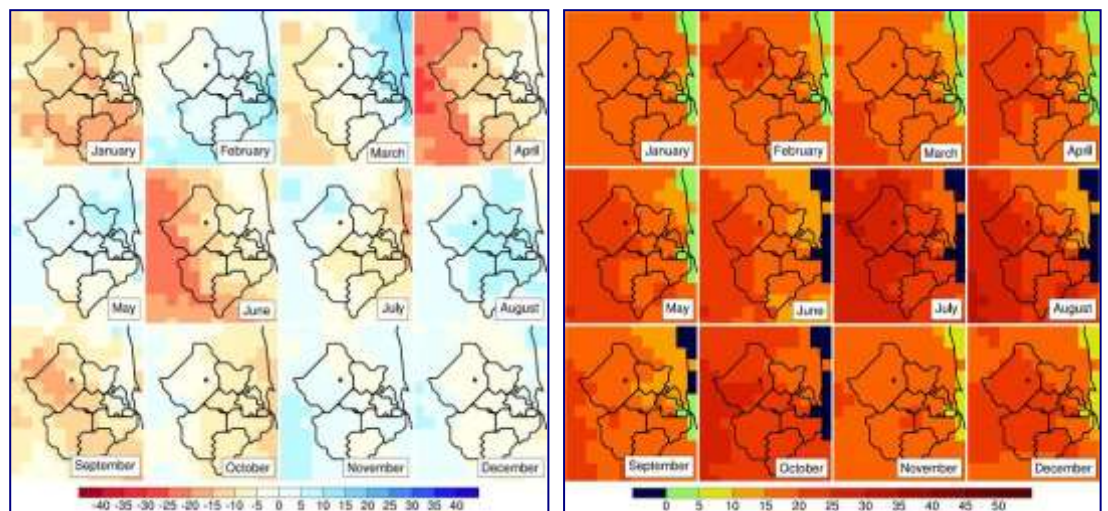


Climate Change Impact on Water Availability in the South East Queensland Region

Matthew Gooda and Sanne Voogt

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The Urban Water Security Research Alliance (UWSRA) is a \$50 million partnership over five years between the Queensland Government, CSIRO's Water for a Healthy Country Flagship, Griffith University and The University of Queensland. The Alliance has been formed to address South East Queensland's emerging urban water issues with a focus on water security and recycling. The program will bring new research capacity to South East Queensland tailored to tackling existing and anticipated future issues to inform the implementation of the Water Strategy.

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Description: Projected monthly rainfall and evaporation change from CSIRO Mk3.5 downscaled using CCAM.
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FOREWORD

Water is fundamental to our quality of life, to economic growth and to the environment. With its booming economy and growing population, Australia's South East Queensland (SEQ) region faces increasing pressure on its water resources. These pressures are compounded by the impact of climate variability and accelerating climate change.

The Urban Water Security Research Alliance, through targeted, multidisciplinary research initiatives, has been formed to address the region's emerging urban water issues.

As the largest regionally focused urban water research program in Australia, the Alliance is focused on water security and recycling, but will align research where appropriate with other water research programs such as those of other SEQ water agencies, CSIRO's Water for a Healthy Country National Research Flagship, Water Quality Research Australia, eWater CRC and the Water Services Association of Australia (WSAA).

The Alliance is a partnership between the Queensland Government, CSIRO's Water for a Healthy Country National Research Flagship, The University of Queensland and Griffith University. It brings new research capacity to SEQ, tailored to tackling existing and anticipated future risks, assumptions and uncertainties facing water supply strategy. It is a \$50 million partnership over five years.

Alliance research is examining fundamental issues necessary to deliver the region's water needs, including:

- ensuring the reliability and safety of recycled water systems.
- advising on infrastructure and technology for the recycling of wastewater and stormwater.
- building scientific knowledge into the management of health and safety risks in the water supply system.
- increasing community confidence in the future of water supply.

This report is part of a series summarising the output from the Urban Water Security Research Alliance. All reports and additional information about the Alliance can be found at <http://www.urbanwateralliance.org.au/about.html>.



Chris Davis
Chair, Urban Water Security Research Alliance

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EXECUTIVE SUMMARY

This report presents an analysis of downscaled climate change projections for South East Queensland (SEQ) by comparing projections from 11 Global Circulation Models (GCMs) and 12 high resolution dynamically downscaled GCMs, using the CSIRO Cubic Conformal Atmospheric Model (CCAM). The study area includes the Brisbane River catchment and the hydrology has been modelled using the Integrated Quality Quantity Model (IQQM), previously developed for use in Water Resource Planning activities.

Climate change projections from each of the models were applied to historical rainfall and evaporation sequences, which were then used to generate the projected inflow sequences required to run the hydrologic models. This provided a comparison of the effect of downscaling on the performance of stream flows and storage behaviour.

Analysis of the downscaled data sets shows significant spatial variability of rainfall projections, with rainfall generally diminishing towards the west of the catchment. This results in further reduced inflows to Wivenhoe and Somerset Dams compared to the original GCM projections, due to a large proportion of the contributing catchment being in the west. Downscaling also shows that the temporal pattern of projected climate change factors from the parent GCMs is not necessarily preserved in the downscaled models, which can result in changing the net effect of the projections from wetter to drier and vice versa.

All of the downscaled models show significant increases in evaporation when compared to their parent GCMs and there is good agreement on the magnitude and direction of change between the climate models. However, rainfall change projections were less consistent across the models analysed. This prompted additional analyses to examine the effect of the evaporation projections in isolation from rainfall change projections. This analysis resulted in the downscaled models showing further reduced inflows and storage performance compared to the GCM projections. It also showed that inflow and storage performance are sensitive not only to projected rainfall changes but also projected evaporation changes.

Significant differences in the impact on water availability were observed between the individual GCM and downscaled climate change projections. The majority of downscaled models show a significant decrease in water availability, measured by an increased frequency of the combined storage volumes of Wivenhoe and Somerset Dams falling below arbitrary storage levels, during the hydrologic model simulation period. While both the GCM and CCAM projections show reduced water availability, there is a greater level of agreement between the CCAM projections and more significant impacts.

Additional models were run to determine the effect of increasing the resolution of downscaling from ~20km to ~8km. This analysis was only conducted for the GFDL CM-21 GCM, due to the large computational requirement of the model runs. It showed that projected climate change factors were highly sensitive to downscaling resolution. Given that the initial ~8km model projections were markedly different to the ~20km projections, two additional models were run to confirm that the source of the difference was not likely to be related to model instability or initial condition issues.

This study has identified that high resolution dynamical downscaling of GCMs results in significant differences to climate change factor projections in the study area. These differences resulted in significant projected reductions in inflow and water availability for Wivenhoe and Somerset Dams, compared to those obtained from the original GCM projections. It has also found that climate change projections are highly sensitive to the resolution of downscaling, which raises the question of how to choose the optimal or suitable downscaling resolution for hydrologic modelling applications.

Further analysis is required to determine the appropriateness of the methodologies used in this study. Particularly, the method used to derive the climate change factors from the downscaled GCM projections needs more work, as does the associated issue of using a single model run for each GCM downscaling experiment instead of an ensemble

1. INTRODUCTION

Recent drought in South East Queensland (SEQ) has prompted further consideration of climate variability and climate change when assessing the security of urban water supplies. This study examines the sensitivity of water availability to the spatial resolution of climate change projections. The Integrated Quality Quantity Model (IQQM) hydrologic model is used to assess the impact of climate change projections from 11 Global Circulation Models (GCMs) and 12 dynamically downscaled GCMs using the CSIRO Cubic Conformal Atmospheric Model (CCAM). This is done by applying climate change projections to long-term historic climate sequences, and analysing the performance of water storages using the IQQM calibrated for the Moreton catchment (Figure 1.1) by the Department of Environment and Resource Management (DERM) (now the Department of Science, Information Technology, Innovation and the Arts (DSITIA)).

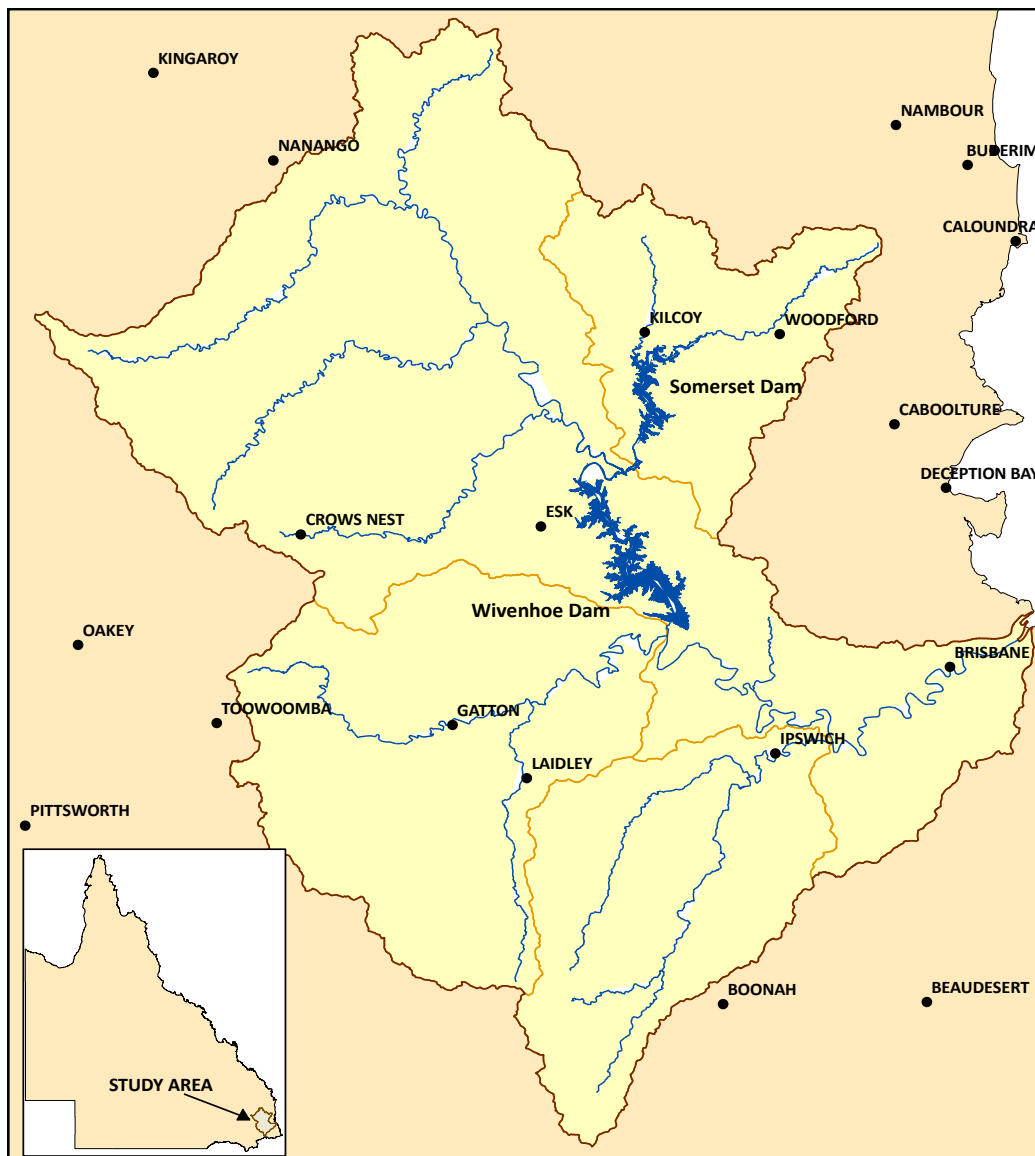


Figure 1.1. Moreton Catchment Map.

Climate change impact has been incorporated into the Moreton IQQM by scaling the historic rainfall, evaporation and streamflow inputs, for each climate change projection. Historic evaporation data for the model has been extracted from the SILO patched point dataset at two evaporation stations.

2. CATCHMENT DESCRIPTION

The Moreton Water Resource Plan (WRP) Area is located in SEQ. The total Plan Area is approximately 15 631 km², consisting of the catchments for the following rivers and creeks:

- Brisbane River
- Pine River
- Cabbage Tree Creek
- Caboolture River, and
- Creeks draining into the western side of the Pumicestone Channel (DERM 2011).

The Brisbane River is a major catchment/basin within the Moreton WRP Area. In general, the Brisbane River is bounded by the Great Dividing Range to the west, and the D'Aguilar Ranges to the east. It rises to the north and flows generally south-east to Moreton Bay. Its major tributaries are the Stanley River, Lockyer Creek and Bremer River.

Land use within the basin is a mixture of state forest, grazing, horticulture and a large proportion of urbanised areas. Included in the catchment are the major cities of Brisbane and Ipswich, and the larger towns of Laidley, Gatton, Esk, Kilcoy and Woodford.

Urban water supply is the major use of water within the catchment. A number of large dams, including Wivenhoe and Somerset Dams that supply Brisbane's urban water, have been constructed to store water for towns and cities in the SEQ region.

There are two significant supplemented irrigation schemes within the basin in the Lockyer and Bremer subcatchments. These schemes provide water for irrigation and urban/industrial supplies. Irrigation supplies are generally for horticulture or irrigated pastures (DERM 2011).

For modelling purposes, the Moreton WRP Area was first divided into its major catchments/basins, of which the Brisbane River is one. The Brisbane River was then subdivided into six major subcatchments (Figure 2.1):

- Upper Brisbane (Brisbane River at Watts Bridge)
- Stanley River (Stanley River at Somerset Dam)
- Central Brisbane (Brisbane River to Wivenhoe Dam)
- Lockyer Creek (Lockyer Creek at O'Reillys Weir)
- Bremer River (to confluence with Brisbane River)
- Lower Brisbane (Brisbane River Wivenhoe Dam to End of System).

These subcatchments were then divided into a total of 40 reaches that are based on the location of significant long-term gauging stations in the catchment. Each reach was further divided into subareas to allow the rainfall and flow variations to be better modelled (DERM 2011).

2.1. Upper Brisbane

The Upper Brisbane has been defined in this model as the Brisbane River upstream of the Watts Bridge gauging station (GS 143005a). The Upper Brisbane represents the Brisbane River upstream of Wivenhoe Dam, before the Stanley River enters the Brisbane. The major tributaries of the Upper Brisbane River are Cooyar Creek, Emu Creek and Cressbrook Creek.

The Upper Brisbane subcatchment is bounded by the Great Dividing Range to the west and Jimna Range to the east. The elevations vary from over 750m in the north, to approximately 100m. The Brisbane River in the upper part of the catchment travels through a relatively incised channel. Towards

the downstream end, the catchment is more open. The majority of the ridge areas are state forest, with grazing areas in the valley.

The Upper Brisbane system is divided into nine reaches according to the locations of gauging stations with reasonable records. Three reaches are on the Upper Brisbane River, three on Cressbrook Creek, two on Emu Creek and one on Cooyar Creek. Cressbrook Creek is a significant groundwater use area, and so simplified groundwater aquifers have been included in the Moreton IQQM and WRP.

Perseverance Creek Dam and Cressbrook Creek Dam are the major storages used to pump town water the to Toowoomba Regional Council area outside the catchment. Cressbrook Dam has a secondary purpose to supplement groundwater aquifers and surface water irrigation within Cressbrook Creek (DERM 2011).

2.2. Stanley

The Stanley has been defined in this model as the Stanley River upstream of Somerset Dam. The Stanley River catchment is bounded by the Conondale Ranges to the north and west, and the D'Aguilar Ranges to the east. Elevations vary from over 800m in the Conondale Ranges to approximately 100m near Somerset Dam. Land use is predominantly state forest due to the steep nature of much of the catchment, with dairying in the valleys and along the river and creek flats.

The Stanley is divided into two reaches according to the locations of gauging stations with reasonable records. The major water infrastructure in this catchment includes Somerset Dam, and two small weirs – Woodford Weir and Kilcoy Weir. Woodford Weir and Kilcoy Weir are primarily used for urban water supply for Woodford and Kilcoy. Somerset Dam is a gated structure used primarily for flood mitigation and to supplement Wivenhoe Dam for urban water supplies. However, it is also used to produce hydroelectric power (DERM 2011).

2.3. Central Brisbane

Central Brisbane has been defined in this model as the Brisbane River bounded by Somerset Dam, Wivenhoe Dam and the Watts Bridge gauge. The major tributaries of the Central Brisbane are Stanley River and Brisbane River (defined by the Upper Brisbane catchment). There are also a number of small tributaries that flow into the Brisbane River above Wivenhoe Dam.

The Central Brisbane catchment is bounded by the D'Aguilar Ranges to the east, and the catchments of the Upper Brisbane and Stanley River to the north and west. Elevations vary from over 500m to approximately 80m near Wivenhoe Dam.

The Central Brisbane system is divided into three reaches according to the locations of gauging stations with reasonable records. Two reaches are on two of the smaller tributaries – Byron Creek and Reedy Creek, and the other is on the Brisbane River to Wivenhoe Dam.

Wivenhoe Dam is the major structure in this section, and is a gated structure that can be operated for flood mitigation, although the primary purpose is for urban water supplies. Hydropower is generated at Wivenhoe Dam through releases to downstream users and through the Splyard Creek Dam system. In the Splyard Creek system, water is pumped from Wivenhoe Dam to Splyard Creek Dam, and then released back into Wivenhoe which drives the hydroelectric turbines. As water is pumped from Wivenhoe and returns generally within the same day, this hydropower release and return has not been modelled.

Prior to the construction of Wivenhoe Dam several waterholes existed along the Brisbane River. The size of these waterholes was determined from historical observations and the topography of the area. They were included within the model during calibration as small storages (DERM 2011).

2.4. Lockyer

The Lockyer Creek system is divided into 12 reaches, based on the locations of gauging stations and storages with reasonable records. These reaches cover the major tributaries of the Lockyer Creek, including Flagstone Creek, Ma Ma Creek, Tenthill Creek, Redbank Creek, Laidley Creek and Buaraba Creek.

Lockyer Creek is bounded by the Great Dividing Range to the west, the Bremer River to the south, and Cressbrook Creek (Upper Brisbane) to the north.

As the Lockyer Creek is a significant groundwater use area that has a significant impact on surface water flows, 26 aquifers have been modelled as simplified storages.

There are two main water supply systems within the Lockyer Catchment: the Central Lockyer, a mainly groundwater supplementation scheme supplied from Lakes Dyer and Clarendon; and the Lower Lockyer, a mainly surface water supplementation scheme supplied by Lake Atkinson (DERM 2011).

2.5. Bremer

The Bremer River in this model is defined as the whole Bremer River catchment to its confluence with the Brisbane River near the city of Ipswich. The catchment is bounded on the east by Teviot Range, to the south by the Great Dividing Range and to the west by the Little Liverpool Ranges. The major tributaries of the Bremer River are Reynolds Creek, Warrill Creek, Purga Creek and Bundamba Creek.

The upstream extents of the Bremer River subcatchment are rugged mountains and ridges with steep slopes, which change gradually to fertile alluvium plains towards the downstream end. The majority of the ridge areas are state forests, with grazing areas in the valley. The Warrill Valley Water Supply Scheme is contained within the Warrill Valley, supplying a significant irrigation area as well as town water supplies.

The lower reach of the Bremer River is affected by the tide and the tidal influence reaches 17.7 km beyond the confluence with Brisbane River. Bundamba Creek is the only major gauged tributary that is affected by the tide in all but high flows.

Moogerah Dam is the major storage inside Bremer River subcatchment. It is a multipurpose storage facility providing water supply and flood mitigation as well as recreation. Water use includes irrigation, town and industrial water supplies.

The Bremer system is divided into seven reaches according to the locations of gauging stations with reasonable records. Two reaches are on the Bremer River and Warrill Creek, and one on each of the Reynolds Creek, Purga Creek and Bundamba Creek. The downstream end of the subcatchment forms an ungauged reach which extends to the Bremer/Brisbane confluence (DERM 2011).

2.6. Lower Brisbane

The Lower Brisbane in this model is defined as the Brisbane River and its tributaries below Wivenhoe Dam, excluding the catchments above Lockyer Creek at O'Reillys Weir and Bremer River at its confluence with the Brisbane River. The major gauged tributaries are Lockyer Creek, Oxley Creek, Enoggera Creek, Bulimba Creek and Moggill Creek. Gold Creek is considered as a gauged tributary in this model, although the recorded data was not used for inflow generation. The Bremer River inflows to the reach are the simulated flows from Reach 37a, that contains some estimated flow data. Together, the Lower Brisbane consists of 11 reaches covering the Brisbane River from Wivenhoe Dam to the estuary.

The Lower Brisbane catchment is bounded by the D'Aguilar Ranges to the east, and the catchments of the Central Brisbane, Bremer and Logan Rivers to the north, west and south. Elevations vary from approximately 400m in the D'Aguilar Ranges to sea level at the mouth of the Brisbane River. A majority of the Lower Brisbane catchment is either rural residential or urban areas. Included in this zone is the City of Brisbane and parts of Ipswich.

The main use of water in this section is for urban supplies, with some supplemented irrigation supplies. Water is released from Wivenhoe Dam to Mt Crosby Weir, where the supply for Brisbane City is extracted for treatment at the Mt Crosby Water Treatment Plant.

Significant dams are Lake Manchester, Enoggera Dam and Gold Creek Dam, all of which are dams that were originally constructed for urban supplies for the emerging City of Brisbane. Enoggera and Gold Creek Dams were constructed in the late 1800s and Manchester began operation in 1916 (DERM 2011).

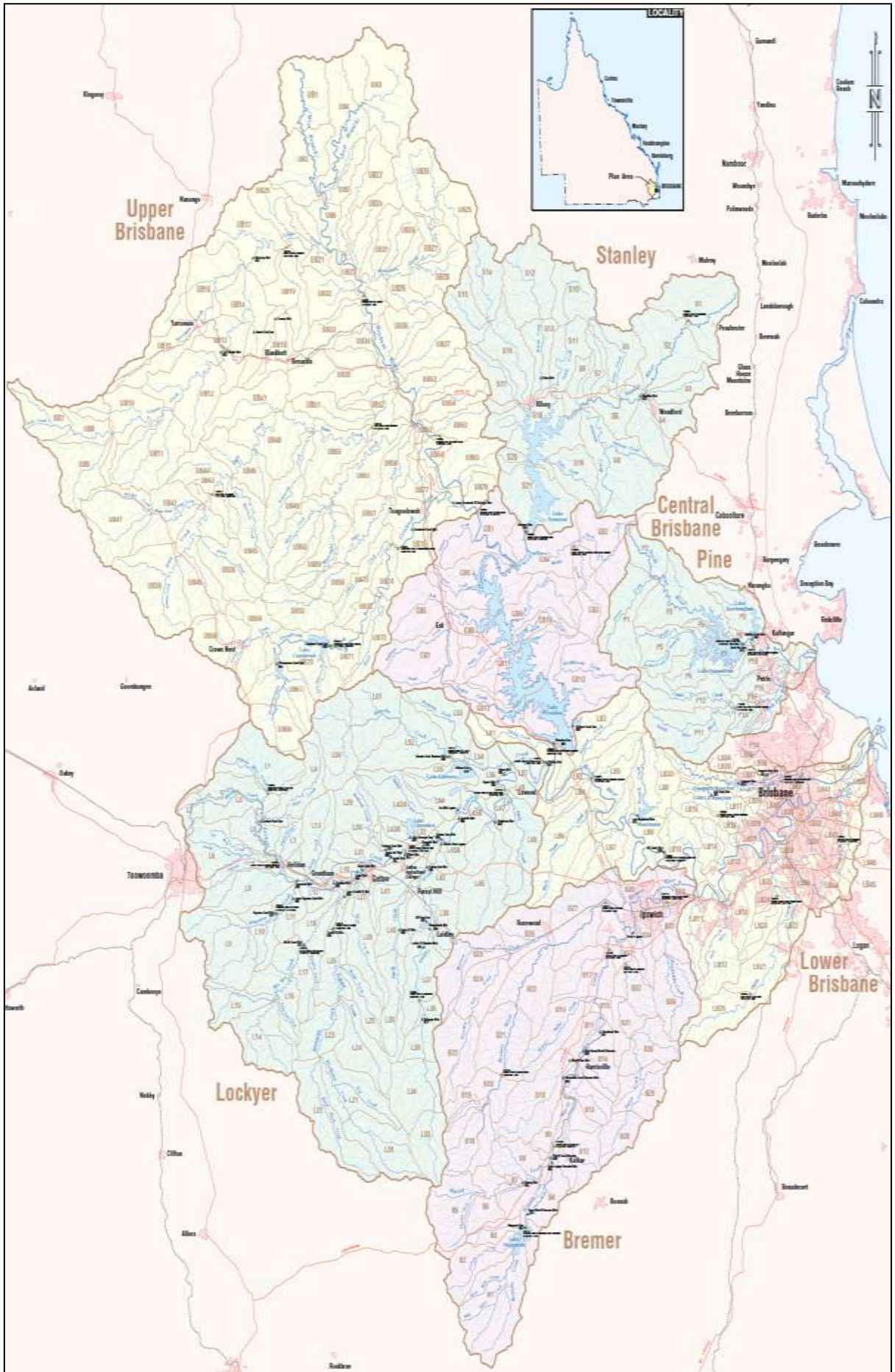


Figure 2.1. Catchment map of the Moreton Water Resource Plan area (with subcatchments).

3. CLIMATE CHANGE IMPACT STUDY MODEL

3.1. Description of IQQM Model Used

The IQQM for the Resource Operations Plan (ROP) of the Brisbane River catchments was used in this study to determine the impact of climate change of water availability in the SEQ region. As described above, the ROP IQQM is in four segments consisting of the Upper Brisbane catchment, the Bremer catchment, the Lockyer catchment and the Stanley, Central Brisbane and Lower Brisbane catchments (see Figure 2.1). The models assume full use of existing high and medium priority entitlements without demand restrictions. The simulation period for the climate change modelling completed was 01/01/1889 to 30/06/2000.

3.2. Relevant IQQM Data

The potential impact of climate change is assessed by applying climate change projections to long-term historic climate sequences. Specifically, the projections are applied to the historic rainfall and evaporation data, and subsequently the influence of these changes on the historic streamflow is determined. The information below describes the origin of the rainfall, evaporation and streamflow data in the historical ROP IQQM and has been sourced from the *Brisbane River IQQM Calibration* report (DERM 2011). The data described below have been used for the historical model runs reported on in this report and have also formed the basis of the climate change adjusted data sets.

3.2.1. Rainfall

3.2.1.1 Derivation of Rainfall Data

For modelling purposes, interpolated daily rainfall data for the period 01/01/1889 to 31/12/2000, the SILO Data Drill dataset, was obtained from the Climate Impacts and Natural Resource Systems (CINRS) group of DERM (<http://www.longpaddock.qld.gov.au/silo/>). The data was provided for the Moreton catchment, which can be enclosed within a box cornered:

- 26° 15' S 151° 30' E
- 28° 15' S 153° 15' E (DERM 2011).

CINRS interpolates the rainfall observations from the Bureau of Meteorology (BoM) rain gauges to generate rasters of estimated daily rainfall. Each raster contains an estimate of the rainfall at every 0.05 degrees across Australia. A description of the methods used to generate these rasters is documented in Jeffrey *et al.* (2001). Essentially, the output from this method is a daily timeseries at 0.05° by 0.05° grid points across the catchment. This gridded data is used to generate daily average subcatchment rainfall for the ~200 subcatchments used in the model.

From this data set, rainfall can be determined for either a point (e.g. town, climate station, dam) or as an average of a number of points (e.g. catchment). For the purposes of IQQM model development and calibration, files of mean daily rainfalls were obtained for each subarea and also for some specific points in the catchment (DERM 2011).

BoM station data was used to derive the rainfall data for the Moogerah Dam inflow derivation and Sacramento rainfall-runoff model calibration. It was found that the grid rainfall derived for Moogerah Dam catchment had lower peaks than expected given recorded rainfall in the area because of the effect of data from stations outside the catchment. Therefore, it was decided to use the recorded station data at Moogerah Dam site (Station 040135), infilled with the adjusted data from surrounding stations (Rockville 040622, Stanfells Upper 041380 and Englesberg Village 040104).

Table 3.1 shows the Mean Annual Rainfall (MAR) for the storages or specific locations that rainfall was required for in the verification models for the Brisbane River IQQM. The mean annual rainfall varies widely across the catchment, from 777 mm/a (Ma Ma Weir) to 1362 mm/a (Woodford Weir). On average, the Stanley River catchment is the wettest part of the Brisbane River catchment, and the Lockyer the driest (DERM 2011).

Table 3.1. Brisbane Mean Annual Rainfall (MAR) – Storage and Point Sites.

Location	Subarea/Point	MAR (mm/a) (01/07/1889 – 30/06/2000)
Ted Pakallus Weir	UB12	811
Boobir Creek Weir	UB14	858
McCauley Weir	UB17	837
Perseverance Dam	UB67	997
Cressbrook Dam	UB70	956
Cressbrook Weir	UB76	863
Lower Cressbrook Weir	UB76	863
Woodford Weir	S4	1362
Kilcoy Weir	S13	1052
Somerset Dam	S21	974
Wivenhoe Dam	CB13	1065
Splityard Storage	LB2	1048
Flagstone Creek Weir	L10	820
Lower Flagstone Weir	L11	807
Carpendale Weir	L12	796
Ma Ma Weir	L17	777
Granthams Weir	L19	806
Gatton Weir	L19	806
Tenthill Ck Weir	L26	767
Tenthill Lower Weir	L27	784
Lake Clarendon	L43	821
Jordan I & II Weir	L31	798
Wilsons Weir	L32	784
Clarendon Weir	L32	784
Mulgowie Recharge Weir	L35	1023
Lake Dyer	L38	795
Showgrounds Weir	L37	848
Sandy Creek Weir	L40	858
Crowleyvale Weir	L42	776
Glenore Grove Weir	L32	784
Kentville Weir	L45	797
Brightview Weir	L45	797
Buaraba Diversion Weir	L52	886
Atkinson Dam	L55	818
Sippels Weir	L57	822
Potters Weir	L52	886
O'Reillys Weir	L57	822
Lake Manchester	Point	916
Mt Crosby Weir	LB9	892
Moogerah Dam	Infilled BoM station data	945
Upper Warrill Diversion Weir	B4	886
Kents Lagoon Diversion Weir	B4	886
Aratula Weir	B7	921
Kents Lagoon	B12	866
Railway Weir	B14	819
Churchbank Weir	B14	819
Gold Creek Dam	LB17a	1232
Enoggera Dam	LB36	1206
Gatton Evaporation Station (040082)	Point	784
Brisbane Evaporation Station (040223)	Point	1174

(Source: DERM 2011)

3.2.1.2 Check on Rainfall Data

Two general checks were performed on the grid rainfall data:

- that the grid rainfall data was comparable to recorded data; and
- the spatial and temporal distribution of rainfall stations.

A check was undertaken to ensure that the grid rainfall data was reliable compared to recorded rainfall data. The grid data for subareas where there was a long-term BoM rainfall station were compared to the BoM rainfall record at the site. It was found that they matched well. A similar check was undertaken specifically for the Perseverance and Cressbrook catchments and showed the same close match of data.

The CINRS group was able to provide, for each station, the number of data points within each decade from 1880. Each station was plotted on a map of the Moreton Basin, along with the number of data points, to indicate the availability and spatial distribution of recorded rainfall data. From this analysis, it appeared that the spread of stations with reasonable numbers of data points was reasonable but there were fewer long-term stations available in the less populated or hilly areas.

Overall, the checks indicated that, over a broad area and over a long period of time, the distribution of stations and data availability at the stations is good and so should produce a reliable interpolation to produce the grid rainfall data. The grid rainfall data matched well to the recorded rainfall data (DERM 2011).

3.2.1.3 Somerset Dam Rainfall Issues

While the model was being calibrated, it was noticed that in the latter years of the calibration the Somerset Sacramento inflows based on the grid rainfall were lower than we had calculated using storage information. The under-estimate of inflow was very apparent in the storage behaviour plot where the Sacramento run showed the storage drawing down faster than it really did. This was traced back to the lack of rainfall stations in the lower south-east Somerset catchment.

In the south-east of the Somerset catchment, there are few rainfall stations and the grid rainfall is based on rainfall from stations to the west of the subareas concerned, which is what you would expect given the topography of the area and lack of recorded data in this area. However, when the Mt Mee (040145) recorded rainfall (from the mountains to the east of the main Stanley River) was used to replace the grid rainfall for the south-east subarea, the inflows were increased and the Somerset storage behaviour plot was more realistic during the period in question; unfortunately the match was not as good in other periods.

In the end, it was decided not to do any adjustments to the grid rainfall data, because for most of the record the grid rainfall run through the Sacramento model gave a good representation of what was going on at Somerset, and the period discussed was adjusted to the Somerset record inflows anyway. This, however, does show that if the recorded rainfall coverage is not good, the grid rainfall may at times not give a true representation of the spatial rainfall (DERM 2011).

3.2.2. Evaporation

3.2.2.1 Recorded Pan Evaporation Data

Data from three evaporation stations was used in the calibration of the model (see Table 3.2). The locations of these stations are in subareas L19, LB30, and C3 respectively, shown in Figure 2.1.

Table 3.2. Brisbane Evaporation Stations.

Station Number	Station Name	Latitude	Longitude	Mean Annual Pan Evaporation July to June (mm/a)	Period of Record	% Data Available
040082	Gatton	27.55	152.34	1793	01/06/1967 – 31/01/2000	95.8
040214	Brisbane Regional Office	27.48	153.03	1578	01/01/1951 – 31/03/1986	99.1
040223	Brisbane AMO	27.42	153.11	1951	02/04/1986 – 14/02/2000	99.5

(Source; DERM 2011)

3.2.2.2 Model Evaporation Data

The lake evaporation and potential evapotranspiration (PET) for the recorded period were calculated using the Morton method (Morton, 1983). The following climatic factors were used in the calculations:

- minimum and maximum daily temperature;
- wet and dry bulb daily temperatures;
- number of hours of sunshine per day;
- latitude; and
- height above sea level.

In addition to evaporative losses for open water surfaces associated with dams, seepage losses can also represent a significant component of overall storage loss. Seepage loss is generally directly related to water level (i.e. greater head drives higher seepage loss), whilst evaporative loss is a function of surface area, which also increases with higher water levels. As such, seepage loss can be indirectly simulated as proportional to evaporative loss by adopting an assumed seepage loss rate which approximates the relationship between water level and loss. The standard departmental approach to simulating seepage loss is to combine a rate of seepage (25 mm/month) with estimated lake evaporation to provide a single daily ‘lake evaporation + seepage’ data set.

Daily lake evaporation and PET were calculated for Gatton and Brisbane sites using two methodologies. The first methodology applied to the Upper Brisbane, Lockyer, Central Brisbane, Stanley and parts of the Lower Brisbane, and the second methodology was applied in the Bremer and parts of the Lower Brisbane.

The first methodology, used for the Upper Brisbane, Lockyer, Central Brisbane, Stanley, and parts of the Lower Brisbane, extended the available daily lake or PET evaporation data for Gatton (040082) and Brisbane (040223 infilled with 040214) using the mean monthly lake or PET evaporation. At the time the evaporation files were created, limited data was available for the calculation of lake and PET evaporation. For this reason, adjustments were based on 01/04/1975 to 30/04/1984 for Gatton, and 01/01/1951 to 30/10/1991 for Brisbane. The data provided for the Brisbane site consisted of 040214 for the period 01/01/1951 to 30/06/1976 and 040223 for the period 01/07/1976 to 30/10/1991.

The mean monthly data was adjusted using the WETDRY program. This program takes the average monthly evaporation and adjusts the daily evaporation based on the rainfall on each day. The rainfalls used to apply WETDRY were point rainfalls developed for the Gatton evaporation station (040082) and the Brisbane AMO station (040223).

The second methodology, used for the Bremer and parts of the Lower Brisbane, used meteorological data stored in the SILO patched point database (<http://www.longpaddock.qld.gov.au/silo/>) and an in-house program, EVAPAUST, to estimate daily lake (evaporation over water) and PET (evaporation over

land) evaporations. The calculations were completed for the period 1889 to 2000 for the Gatton (040082) evaporation station and for the period 1889 to 2006 for the Brisbane Regional Office (040214) evaporation station.

The second methodology was adopted for the Bremer and parts of the Lower Brisbane to take advantage of updated data sets and the additional variation in daily evaporation that the second methodology allowed.

Table 3.3 summarises the evaporation data used in the models for the common period of simulation, 1889 to 2000. Although a longer period of data was used for modelling of the Lower Brisbane storages, statistics of the longer dataset are not shown here. The longer period of record had negligible effect on the statistics of the data. The mean annual pan evaporation data that is shown is the data that was available at the time of calibration. In the case of the data for the first methodology, the full period of record was not available (DERM 2011).

Table 3.3. Mean Annual Evaporation Data.

Station Number	Station Name	Subcatchment	Mean Annual Lake + Seepage 01/07/1889 – 30/06/2000 (mm/yr)	Mean Annual PET 01/07/1889 – 30/06/2000 (mm/yr)
040082	Gatton	Upper Brisbane Lockyer Central Brisbane	1679	1873
040082 (SILO)	Gatton	Bremer	1831	1921
040223/ 040214	Brisbane	Stanley Lower Brisbane	1747	1980
040214 (SILO)	Brisbane	Lower Brisbane – Lake Manchester, Enoggera Dam, Gold Creek Dam	1917	2060

(Source: DERM 2011)

3.2.3. Streamflow

Streamflow data for the reaches with flow record at the downstream point was extracted from HYDSYS (Surface Water Database).

The Mt Crosby overflow data from HYDSYS was extended using:

- level data collected from the Queensland State Archives (MWSSB, 1896);
- level data collected from Brisbane City Council/Brisbane Water, and
- ratings available from an earlier hydrology report (IWSC, 1977) and from Brisbane City Council.

For reaches with storages at the downstream point, storage inflows were derived using a variety of information that is described in detail in *Summary of Available Storage Data and Future Data Requirements for the Brisbane and Pine River Systems* (NRW, 2008c).

Table 3.4 shows the HYDSYS gauge data, the storage inflow derivation (SID) data, and the manipulated Mt Crosby data that was used and how it was combined to obtain a flow record for the end of each reach. From this point onwards in this report, unless the gauging station is being specifically referred to, the ‘Gauge’ refers to the combined flow sequence (DERM 2011).

Table 3.4. Brisbane River Gauge Combination.

Reach	Reach Name	Gauge	Data Used	Period
1	Cooyar Ck at Damsite	143015b	143012a x 2.17 143015a 143015a	22/11/1965 – 01/10/1968 02/10/1968 – 10/12/1990 22/12/1990 – 31/12/2000
2	Brisbane River at Linville	143007a	143007a Infill any missing data with 143018a x 1.34	18/10/1964 – 31/12/2000 03/09/1970 – 07/07/1986
3	Emu Ck at Raeburn	143011a	143011a	23/11/1965 – 08/07/1986
4	Emu Ck at Boat Mountain	143010b	143010a 143010b	22/11/1965 – 08/11/1976 26/11/1976 – 31/12/2000
5	Brisbane River at Gregors Ck	143009a	143002a x 0.98 143002b x 0.98 143009a	03/01/1920 – 02/10/1931 03/10/1931 – 07/02/1962 08/02/1962 – 31/12/2000
6a	Perseverance Ck at Perseverance Dam		Derived Inflows	26/08/1965 – 31/12/2000
6b	Cressbrook Ck at Damsite	143013a	143013a Derived Inflows	02/11/1965 – 13/05/1981 02/01/1988 – 31/12/2000
7	Cressbrook Ck at Rosentreter's Bridge	143921a	143006a x 1.17 143921a	02/10/1952 – 09/04/1986 22/08/1986 – 31/12/2000
8	Brisbane River at Watts Bridge	143005a	143005a	03/10/1952 – 30/10/1972
9	Stanley River at Peachester	143303a	143303a	02/07/1927 – 31/12/2000
10	Stanley River at Somerset Dam	143305a	143301a x 1.08 143301b x 1.09 143302a 143305a Derived Inflows Derived Inflows	01/07/1912 – 27/02/1915 03/07/1915 – 02/11/1919 03/11/1919 – 30/09/1941 06/01/1943 – 30/06/1959 02/07/1959 – 31/12/1983 02/07/1986 – 31/12/2000
11	Reedy Ck Upstream Byron Junction	143306a	143306a	27/06/1975 – 31/12/2000
11a	Byron Ck at Causeway	143307a	143307a	25/06/1975 – 31/12/2000
12	Brisbane River at Wivenhoe Dam	143035a	143008a x 1.05 143026a 143008a x 1.05 Derived Inflows	02/10/1962 – 20/06/1974 21/06/1974 – 05/04/1977 06/04/1977 – 11/08/1982 15/11/1986 – 31/12/2000
13	Fifteen Mile Ck at Damsite	143208a	143208a	30/06/1956 – 01/10/1987
14	Lockyer Ck at Helidon #3	143203c	143202a x 1.32 143203a 143203b x 0.93 143203c	02/11/1919 – 30/06/1926 02/07/1926 – 01/10/1965 02/10/1965 – 18/05/1986 21/11/1987 – 31/12/2000
15	Flagstone Ck at Windolfs	143214a	143214a	03/02/1972 – 31/12/1986
16	Ma Ma Ck at Ma Ma Weir	143213b	143213a 143213b	24/02/1972 – 09/01/1976 02/04/1977 – 03/03/1986
17	Tenthill Ck at Tenthill	143212a	143212a	19/03/1968 – 31/12/2000
99	Redbank Ck at Water Treatment Plant	143216a	143218a x 1.09 Fill any missing data with 143216a	16/12/1975 – 20/09/1983 17/12/1975 – 24/08/1986
18	Lockyer Ck at Wilsons Weir	143204a	143204a	02/10/1953 – 17/04/1977
19	Laidley Ck at Mulgowie 2	143209b	143209a 143209b	25/01/1957 – 30/12/1962 08/03/1967 – 31/12/2000
20	Lockyer Ck at Rifle Range Rd	143210b	143201a x 1.04 143201b x 1.04 143206a x 1.04 143210a 143210b	02/10/1909 – 02/10/1925 03/10/1925 – 29/06/1947 02/10/1953 – 21/04/1964 22/04/1964 – 02/02/1988 03/02/1988 – 31/12/2000
21	Buaraba Ck at 15.8 km	143211a	143211a	22/02/1967 – 11/07/1979
21a	Atkinson Dam		Derived Inflows	02/08/1970 – 31/12/2000
22	Lockyer Ck at O'Reillys Weir	143207a	143207a	13/01/1948 – 31/12/2000

Reach	Reach Name	Gauge	Data Used	Period
23	Bremer River at Adams Bridge	143110a	143104a x 1.62 143104b x 1.87 and infill missing record in 143110a	16/02/1919 – 01/10/1952 02/10/1952 – 22/02/1969 23/02/1969 – 28/02/1973 23/02/1969 – 31/12/2000
24	Bremer River at Walloon	143107a	143107a	03/10/1961 – 31/12/2000
25	Reynolds Ck at Moogerah Dam HW	143111a	143103a x 1.19 143103b x 1.19 Derived Inflows	02/10/1917 – 01/10/1954 02/10/1954 – 30/09/1960 26/01/1971 – 31/12/2000
26	Warrill Ck at Kalbar #2	143102b	143102a x 1.01 143102b	26/10/1912 – 01/10/1958 02/11/1958 – 28/02/1971
27	Warrill Ck at Amberley	143108a	143101a x 1.19 143108a	02/07/1914 – 15/03/1954 03/10/1961 – 31/12/2000
28	Purga Ck at Loamside	143113a	143113a	25/11/1973 – 31/12/2000
29	Bundamba Ck at Mary St	143114a	143114a	03/08/1972 – 27/01/1983
30	Brisbane River at Savages Crossing	143001c	143001a x 1.01 143001b x 1.01 143001c	14/07/1909 – 02/10/1950 03/10/1950 – 02/10/1958 03/10/1958 – 31/12/2000
31a	Cabbage Tree Ck at Lake Manchester		Derived Inflows	01/01/1985 – 28/02/2006
31	Brisbane River at Mt Crosby	143003a	143003a (Overflows derived from levels from State Archives and the 1977 study rating curves)	13/08/1896 – 01/01/1900
			143003a (HYDSYS)	02/01/1900 – 22/09/1918
			(Data removed because of suspected interference by sandbagging of weir during summer months)	(06/10/1911 – 08/02/1912 15/10/1912 – 12/11/1912 29/11/1913 – 29/01/1914 29/11/1914 – 29/12/1914 18/09/1915 – 27/10/1915 01/01/1916 – 02/02/1916 07/09/1917 – 24/09/1917)
			Data not used due to weir construction work affecting derived overflows	23/09/1918 – 30/12/1926
			Missing Data	01/01/1927 – 01/01/1928
			143003a (HYDSYS)	02/01/1928 – 01/01/1975
	Daily overflows derived from height data and overflow ratings. See GS Report for details (NRW, 2008b)	02/01/1975 – 31/12/2000		
32	Moggill Ck at Upper Brookfield	143032a	143020a x 0.38 143032a	25/05/1972 – 13/07/1976 14/07/1976 – 31/12/2000
33	Oxley Ck at New Beith	143033a	143019a x 0.39 (not used) 143033a	25/12/1971 – 29/12/1974 12/12/1976 – 31/12/2000
34	Blunder Ck at King Ave Bridge	143027a	143027a	27/10/1973 – 15/03/1979
35a	Enoggera Ck at Enoggera Dam		Derived Inflows	01/01/1989 – 28/02/2006
35b	Enoggera Ck at Bancroft Park	143932a	143932a	21/11/1971 – 28/10/1981
36	Bulimba Ck at Mansfield	143094a	143004a x 1.12 Missing Data 143004a x 1.12 143094a	11/12/1949 – 28/09/1961 29/09/1961 – 13/10/1966 14/10/1966 – 27/06/1971 02/08/1971 – 25/03/1996
37c	Gold Ck at Gold Creek Dam		Derived Inflows	01/01/1975 – 28/02/2006

(Source: DERM 2011)

4. CLIMATE CHANGE IMPACT MODELLING APPROACH

4.1. Overview

Future climate sequences for rainfall and evaporation are produced for each of the GCMs and dynamically downscaled climate models by scaling the long-term, historic daily climate sequences (1889 to 2000). The methodology is explained in Section 5.2.

Table 4.1 lists the combinations of models and emissions scenarios analysed. The 12 downscaled GCMs presented are the only models available for this study so far, and the 11 GCMs used have been selected by Queensland Climate Change Centre of Excellence (QCCCE), from the 23 International Panel on Climate Change AR4 GCMs, as the most appropriate for assessing the impact of climate change on rainfall in Queensland. The 12 original dynamically downscaled models used the Conformal-Cubic Atmospheric Model (CCAM) and were downscaled to a 20km grid.

Table 4.1. List of GCMs and Downscaled GCMs used in this study.

Model	Emissions Scenario	GCM	CCAM				
			~20 Km			~8 Km	
			CCAM	CCAM PPE1	CCAM PPE2	CCAM PPE1	CCAM PPE2
CSIRO Mark 3.0	A2	✓	✓				
	A1B		✓				
CSIRO Mark 3.5	A2	✓	✓				
GFDL CM 2.1	A2	✓	✓	✓	✓	✓	✓
IAP FGOALS 1.0	A1B	✓					
INMCM 3.0	A2		✓				
	A1B		✓				
MIROC 3.2 (medres)	A2	✓	✓				
MIROC 3.2 (hires)	A1B	✓					
MIUB echo	A2	✓					
MPI ECHAM 5	A2	✓	✓				
NCAR CCSM 3.0	A2	✓	✓				
	A1B		✓				
UKMO HADCM3	A2	✓	✓				
UKMO HADGEM1	A2	✓	✓				

Downscaled factors were also generated for the GFDL CM 2.1 model for both a 20km and 8km grid size using the CCAM with two variants of perturbed parameters (Perturbed Physics Experiments 1 and 2), as shown in Table 4.2. GFDL CM 2.1 factors were generated using all of the described methods, and provide a comparison of the impact of regional downscaling and the sensitivity of downscaling resolution.

Eight of the models used provide a direct comparison between the original GCM and downscaled GCM climate change projections, with the additional models contributing to the separate GCM and downscaled GCM ensembles.

The projected influence of climate change on rainfall is variable and uncertain, while the projections of evaporation change are much more reliable and consistent across the range of climate models. Hence, an assessment of the system performance considering only evaporation change (and inflow)

was also completed for the full set of models shown in Table 4.1. It was assumed that there was no projected change in rainfall for these runs.

Table 4.2. Description of Generation Method.

Generation Method	Gridsize	Description
GCM	Ranging from 100 to 400km	Global circulation models developed by various research institutes around the world.
CCAM	~20km	Original dynamically downscaled models using the Conformal-Cubic Atmospheric Model (CCAM) – downscaled to 20km.
CCAM PPE1	~ 8km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 8km.
CCAM PPE1	~20km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 20km.
CCAM PPE2	~ 8km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with other changes to uncertainty physical parameters (Perturbed Physics Experiment 2 (PPE2)) – downscaled to 8km.
CCAM PPE2	~20km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with other changes to uncertainty physical parameters (Perturbed Physics Experiment 2 (PPE2)) – downscaled to 8km.

As mentioned above, the climate change adjusted rainfall, evaporation and flow data is run through the pre-existing IQQM for the study area. Comparisons were made between the historic and climate change scenarios for both the input data and the model output. Six subcatchments were focussed on for these comparisons – a description of the location of the subcatchments can be found in Table 4.3 and Figure 4.1. These particular focus catchments were selected to demonstrate the spatial variability of projected climate change across the catchment.

Table 4.3. Focus Subcatchments.

Subcatchment	Location
Subcatchment B1	A headwater reach in the Bremer catchment – located at the southern most point of the Moreton WRP area.
Subcatchment CB5	A subcatchment at the upstream end of Lake Wivenhoe in the Central Brisbane catchment – located in the middle of the Moreton WRP area.
Subcatchment L10	A subcatchment in the Lockyer subarea – located in the southwest of the Moreton WRP area.
Subcatchment S1	A headwater reach in the Stanley catchment – located in the northeast of the Moreton WRP area.
Subcatchment UB1	A headwater reach in the Upper Brisbane catchment – located in the north of the Moreton WRP area.
Subcatchment UB7	A headwater reach in the Upper Brisbane catchment – located at the western most point of the Moreton WRP area.

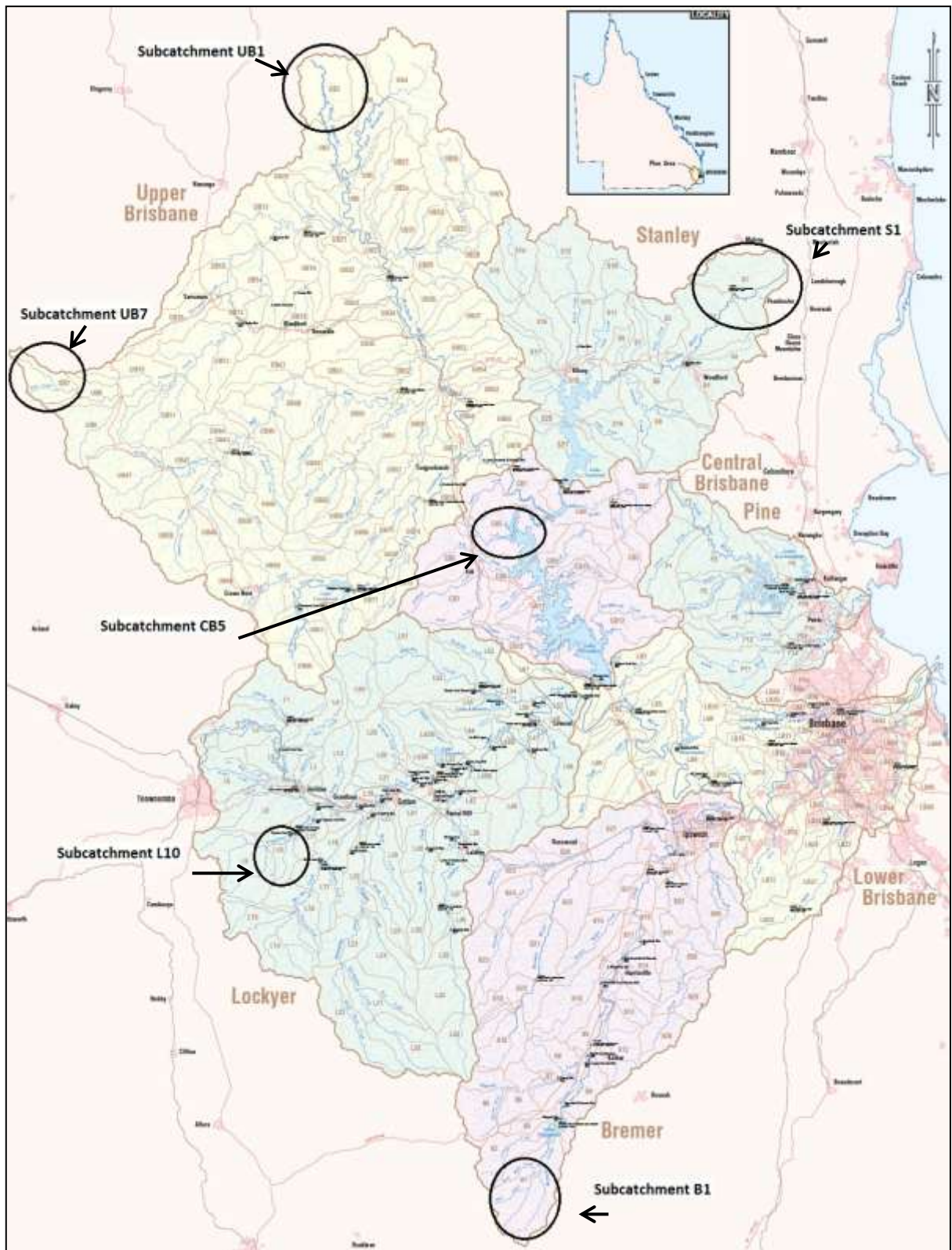


Figure 4.1. Map of Moreton Water Resource Plan Area with Focus Subcatchments highlighted.

4.2. Description of Climate Change Factors

The term ‘climate change factor’ refers to the change in the climatological mean of a specific climate variable (e.g. rainfall, evaporation, temperature) between the current climate (defined in terms of a suitable 20th Century base period) and a projected time in the future (for example, the 30 years centred on 2050). The climate change factors used for this study are calculated on a monthly basis for the year 2050.

Scaling factors are calculated on a monthly basis, for each model, by determining the per degree of global warming response for each climate variable, multiplied by the best estimate of the change in temperature for the year 2050 under emissions scenario A1FI (from Table 4.3 of the Climate Change in Australia Report, 2007). The climate change adjusted rainfall and evaporation files are then used together with a previously calibrated Sacramento model to generate each of the climate change adjusted flow sequences. The climate change adjusted rainfall, evaporation and flow data is then run through the pre-existing IQQM model for the area. In this manner, historical data model outputs can be compared to climate change model outputs for various scenarios. This is consistent with the methodology that has been adopted by DERM for climate change analysis throughout Queensland, and provides a platform for comparing projections from GCMs that have been run under differing emissions scenarios.

4.3. Application of Climate Change Factors to Historical Data

4.3.1. Global Circulation Model Method (GCM)

4.3.1.1 Climate Change Rainfall Generation

Climate change adjusted rainfall sequences were generated for the Moreton catchment for each of the GCMs. The projected monthly scaling factors supplied by QCCCE for each model were applied to the daily historical rainfall sequences for the Moreton catchment (see Appendix A for full explanation of climate change rainfall generation). For each GCM, the same monthly factors were applied to all of the rainfall files in the model (see Appendix B Table 7.1, Table 7.2, Table 7.3 and Table 7.4 for a list of rainfall files). This resulted in climate change rainfall sequences for each of the 12 GCMs.

4.3.1.2 Climate Change Evaporation Generation

As previously mentioned, some of the GCMs did not include a projected change in the evaporation, so the evaporation adjustment had to be estimated. The process of estimating evaporation as part of this methodology included developing a relationship between the annual evaporation and annual temperature factors for the six GCMs which included both factors. For the models which did include projected evaporation factors, this relationship was used to determine the annual change in evaporation for the models which included temperature but did not calculate evaporation. The estimated annual evaporation was then disaggregated to monthly factors based on the evaporation pattern of the model which had the most similar annual evaporation change (see Appendix A for a more detailed explanation of this process). Once the monthly evaporation factors had been determined for the GCMs, they were applied to the daily historical evaporation sequences in the Moreton IQQM (see Appendix B Table 7.5, Table 7.6, Table 7.7 and Table 7.8 for a list of evaporation files in the Moreton catchment).

4.3.1.3 Climate Change Flow Generation

The climate change rainfall and evaporations were then used to estimate the flows in the various subcatchments in the IQQM using the Sacramento rainfall-runoff model (Burnash, Ferral and McGuire 1973). The Sacramento models used had been previously calibrated for each subcatchment using historical rainfall, evaporation and flow data. In order to determine the influence of climate change, the flows generated by the Sacramento model using the climate-change rainfall and evaporation data were compared to the flows generated by the Sacramento model using historical rainfall and evaporation data. For each month, the relationship between these two data sets was then

applied to the historical flow sequences in order to produce a climate-change flow sequence (see Appendix A for a detailed explanation). Figure 4.2 shows an example of the daily flow duration curves for the historical and climate change Sacramento flow for a particular month. The relationship between these curves, on a monthly basis, is applied to the daily historical flow sequences.

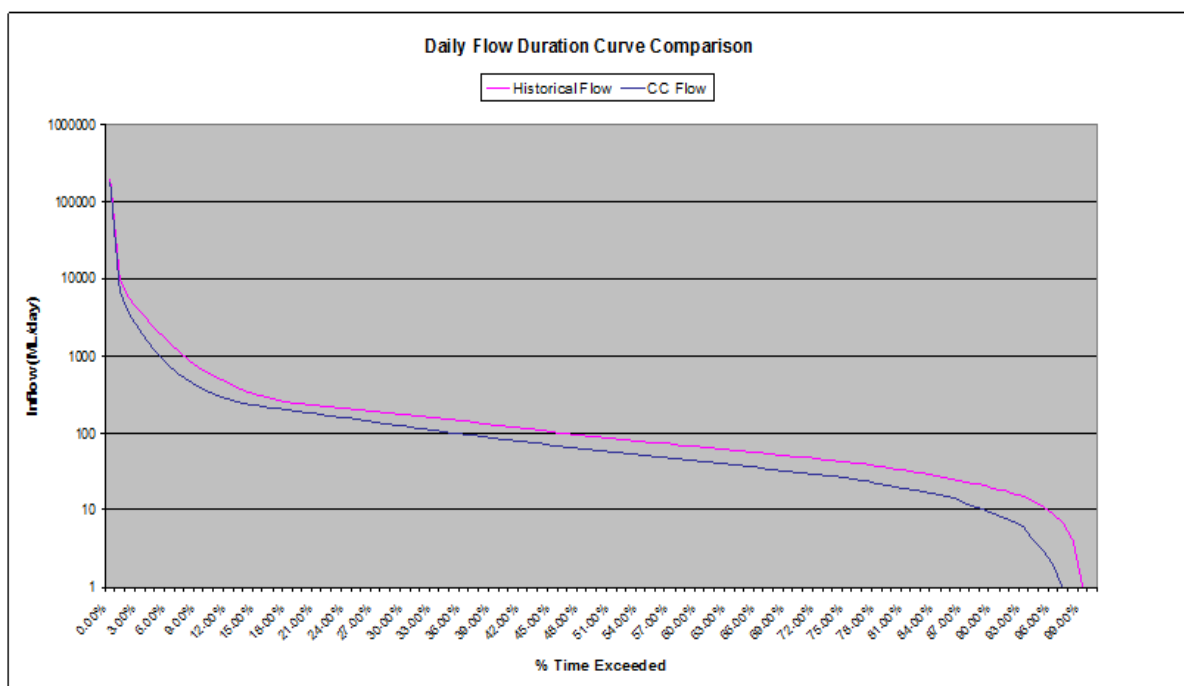


Figure 4.2. Relationship between Historical and Climate Change Sacramento Flow.

4.3.2. Dynamically Downscaled Method (CCAM)

4.3.2.1 Climate Change Rainfall Generation

The process of generating dynamically downscaled climate change adjusted rainfall is different from the method above only with respect to the factors which are used. For the GCM method, there is one set of monthly climate change factors which are applied to all the rainfall files in the system, while for the CCAM method there are different factors for each rainfall file due to the reduced grid size as a result of the downscaling. The monthly factors for each rainfall file and for each climate model were applied to the relevant daily historical rainfall sequences. For each dynamically downscaled GCM, different monthly factors were applied to all of the rainfall files in the model (see Appendix B Table 7.1, Table 7.2, Table 7.3 and Table 7.4 for a list of rainfall files).

4.3.2.2 Climate Change Evaporation Generation

In contrast to the GCM method, all downscaled models produce evaporation output. As with the downscaled rainfall, different monthly climate change factors were provided for each evaporation sequence in the model due to the comparatively small grid size. The monthly factors for each evaporation file and for each climate model were applied to the relevant daily historical evaporation sequences. For each dynamically downscaled GCM, different monthly factors were applied to all of the evaporation files in the model (see Appendix B Table 7.5, Table 7.6, Table 7.7 and Table 7.8 for a list of evaporation files).

4.3.2.3 Climate Change Flow Generation

The process for generating climate change flows is the same as that mentioned above in the GCM Method. The climate change rainfall and evaporations were used to estimate the flows in the various subcatchments in the IQQM using the Sacramento rainfall-runoff model (Burnash, Ferral and McGuire 1973). The flows generated by the Sacramento model using the climate-change rainfall and evaporation data were compared to the flows generated by the Sacramento model using historical rainfall and evaporation data. For each month, the relationship between these two data sets was then applied to the historical flow sequences in order to produce a climate-change flow sequence (see Appendix A for a detailed explanation). The relationship between these curves, on a monthly basis, is applied to the daily historical flow sequences.

4.3.3. Comparison of GCM and CCAM Input

4.3.3.1 Climate Change Factors

Monthly scaling factors were provided for each of the climate models. The GCM factors for each climate model are the same across all catchments and subareas, due to the large grid size. Hence, there are 11 sets of monthly GCM factors in total. For the downscaled models, due to the smaller grid sizes of either 20km or 8km, the monthly scaling factors are different across the various sub-catchments. As a result, there are many sets of monthly factors for each of the 12 downscaled GCMs.

Table 4.4. Description of Relevant Generation Methods.

Generation Method	Grid Size	Description
GCM	Ranging from 100 to 400km	Global circulation models developed by various research institutes around the world.
CCAM	~20km	Original dynamically downscaled models using the Conformal-Cubic Atmospheric Model (CCAM) – downscaled to 20km.

Due to the nature of the downscaled climate models, there is spatial variation in the monthly scaling factors across the catchment. Figure 4.3 shows the monthly projected rainfall change factor for the GFDL CM21 climate model for the GCM and CCAM methods (see Table 4.4 for relevant methods). As mentioned above, there is one set of monthly GCM scaling factors for each climate model across the catchment. The range of downscaled climate change factors shown on the plot are for the six focus subcatchments (see Table 4.3). As can be observed from the plot, the downscaled rainfall change factors vary for each month, and do not always follow the temporal pattern from the GCM.

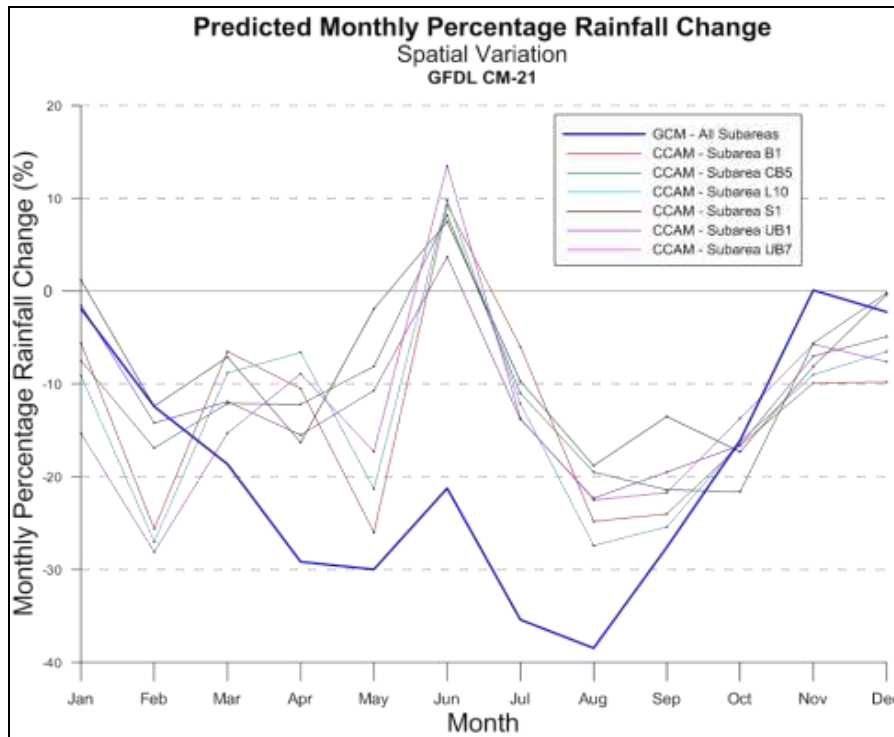


Figure 4.3. Spatial variation of projected monthly percentage rainfall change – GCM and CCAM (GFDL CM-21).

For example, in June, the GFDL CM21 GCM is projecting a decrease in rainfall of ~20%, while the downscaled factors for the same climate model project an increase in rainfall of between ~4 to ~14%. For most other months, the direction of projected rainfall change is the same between the GCM and CCAM methods, but there can be significant differences in the magnitude of change. Rainfall change factor plots for the other seven common climate models (see Table 4.1) can be found in Appendix C - Section C.1. The other plots are similar to Figure 4.3 in that the downscaled model factors generally show the same pattern, while when compared to the GCM factors the magnitude and direction of projected change can be quite different. There are only a few evaporation stations used in the modelling of the Moreton catchment, hence the same spatial variation does not apply to evaporation across the focus subcatchments.

There is also significant monthly scaling factor variation between the different climate models for the GCM and CCAM generation methods (see Table 4.4 for relevant methods). Figure 4.4 shows the variation in projected percentage rainfall change for the GCM generation method for the eight common climate models (see Table 4.1). As can be observed from the plot, some months show more monthly factor variation than others. For example, in April GFDL CM21 projects a ~30% decrease in rainfall, while MIROC 3.2 medres projects a ~30% increase in rainfall. In contrast, the projected rainfall change in January varies only from a decrease of ~2% to an increase of ~15% for these two models respectively.

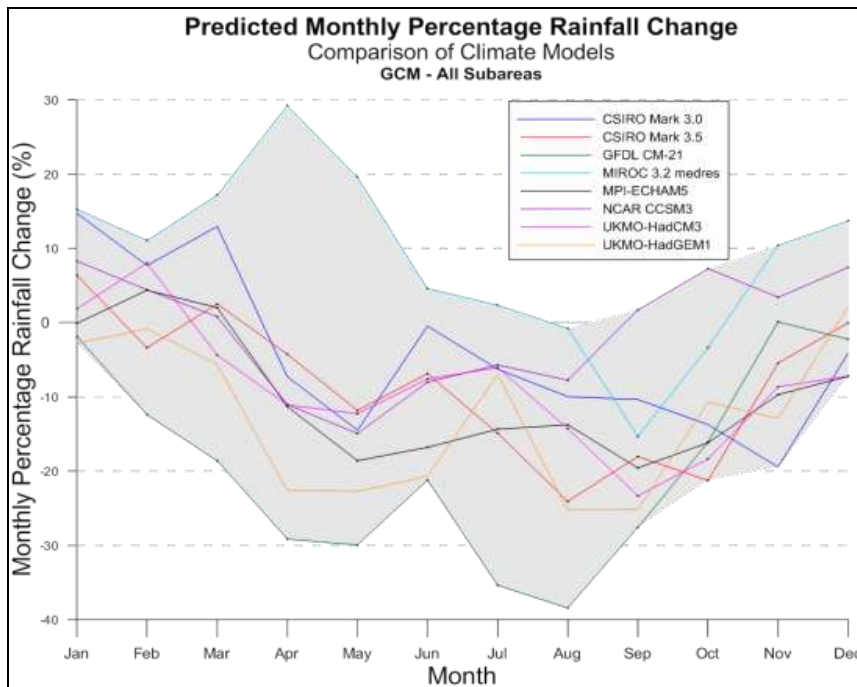


Figure 4.4. GCM variation of projected monthly percentage rainfall change – Whole Catchment.

Substantial variation in rainfall change projections can also be observed for the CCAM generation method (see Figure 4.5 for subarea UB7 climate change factors). July shows the most variable projected change with projections ranging from a ~50% decrease to a ~10% increase. In contrast, December shows only ~15% variation between climate model projections. The five other focus catchments show similar variation in projected rainfall change for the eight common climate models (see Table 4.1). The plots of the projected downscaled rainfall change for the other focus subareas can be found in Appendix C – Section C.2.1.

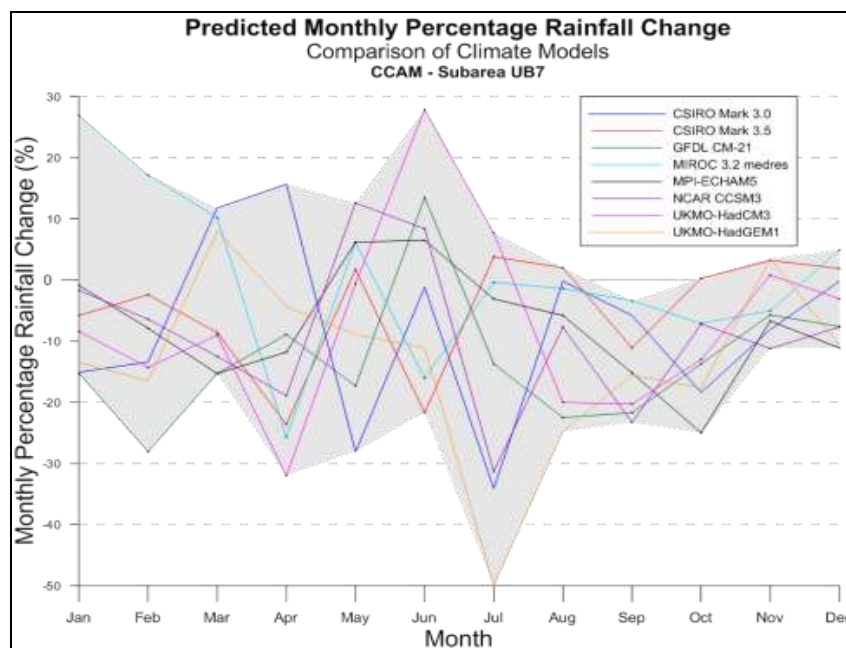


Figure 4.5. Downscaled CCAM variation of projected monthly percentage rainfall change – Subarea UB7.

For both generation methods (Table 4.4) there is generally less variation between the climate models for projected monthly evaporation change. For the GCM generation method, the projected monthly evaporation change displays a range of between ~6% and ~13% difference (see Figure 4.6). The largest projected evaporation change is an increase of ~16.5% for the CSIRO Mark 3.0 climate model in June and July. The downscaled generation method shows more variation than the GCM generation method (see Figure 4.7). The range of projected monthly evaporation change varies from ~6% to ~20% difference, with the highest projected evaporation change occurring under UKMO HadGEM1 in September (~33% increase).

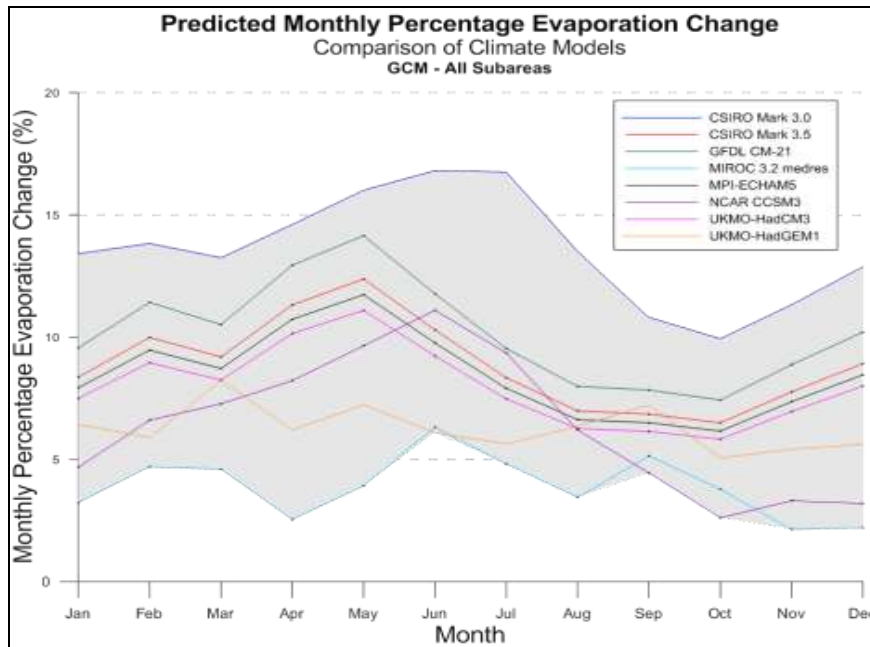


Figure 4.6. GCM variation of projected monthly percentage evaporation change – Whole Catchment.

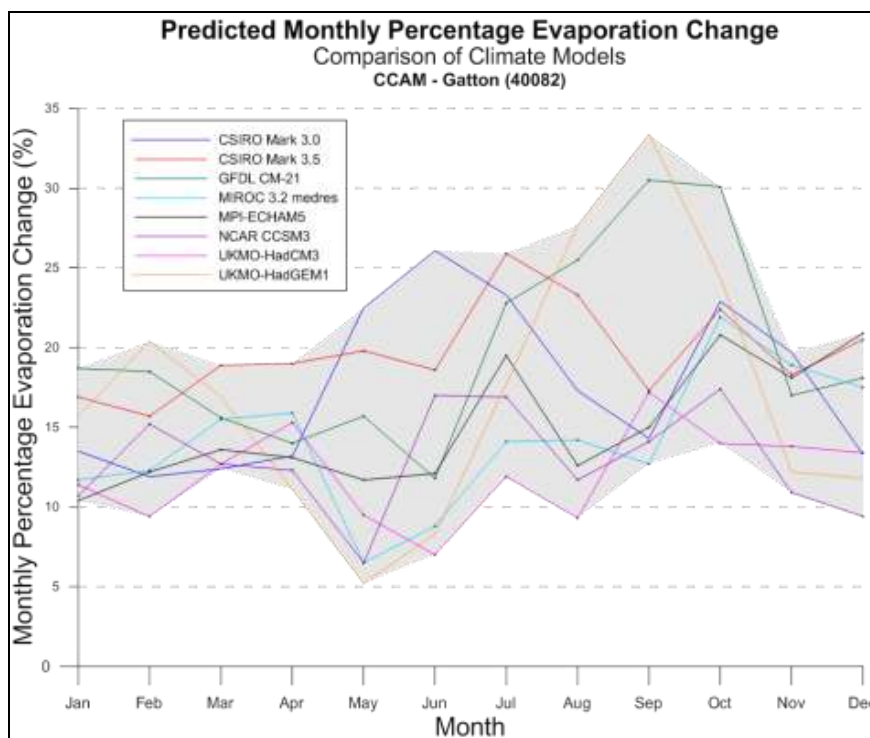


Figure 4.7. CCAM variation of projected monthly percentage evaporation change – Gatton (40082).

As well as variation within generation methods, there is also variation in projected climate change between methods. A comparison of the GCM, original CCAM and the first CCAM perturbed physics experiment methods (see Table 4.5) under GFDL CM21 shows quite a significant difference in both projected rainfall and projected evaporation change (see Figure 4.8 and Figure 4.9). The most notable difference is between the projected factors for the 8km downscaled case (CCAM PPE1) and all of the other generation methods. In June in particular, the 8km CCAM PPE1 case projects an ~85% decrease in rainfall and an ~105% increase in evaporation. In comparison to the 8km CCAM PPE1 generation method, the other generation methods project between a 20% decrease and a 10% increase in June rainfall (see Figure 4.8). In terms of projected evaporation change, the other generation methods project a 10% to 40% increase in evaporation in June, compared to the ~105% increase projected by 8km CCAM PPE1 (see Figure 4.9).

Table 4.5. Description of Relevant Generation Methods.

Generation Method	Grid Size	Description
GCM	Ranging from 100 to 400km	Global circulation models developed by various research institutes around the world.
CCAM	~20km	Original dynamically downscaled models using the Conformal-Cubic Atmospheric Model (CCAM) – downscaled to 20km.
CCAM PPE1	~ 8km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 8km.
CCAM PPE1	~20km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 20km.

Only the projected rainfall change for subcatchment UB7 is shown in the figure below (Figure 4.8), plots of the projected rainfall change for the other five focus subcatchments can be found in Appendix C – Section C.3. The other subareas show similar results in terms of the projected rainfall change, with the 8km CCAM PPE1 case producing a significant decrease in rainfall in June and displaying very different projections compared to the other generation methods.

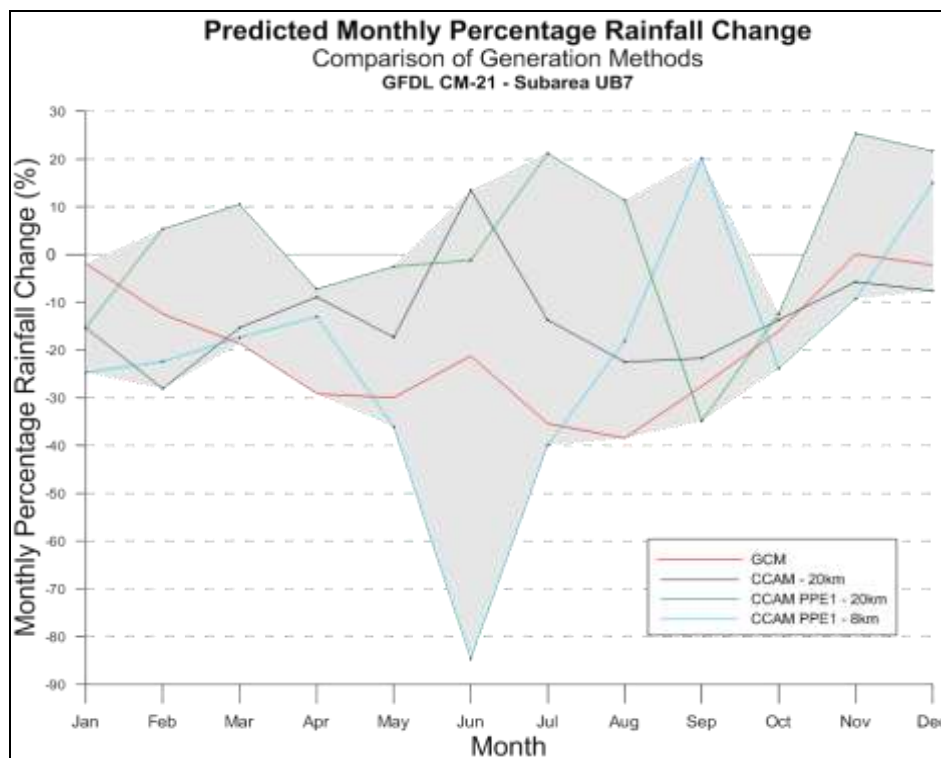


Figure 4.8. Generation method variation of projected monthly percentage rainfall change – GFDL CM-21 – Subarea UB7.

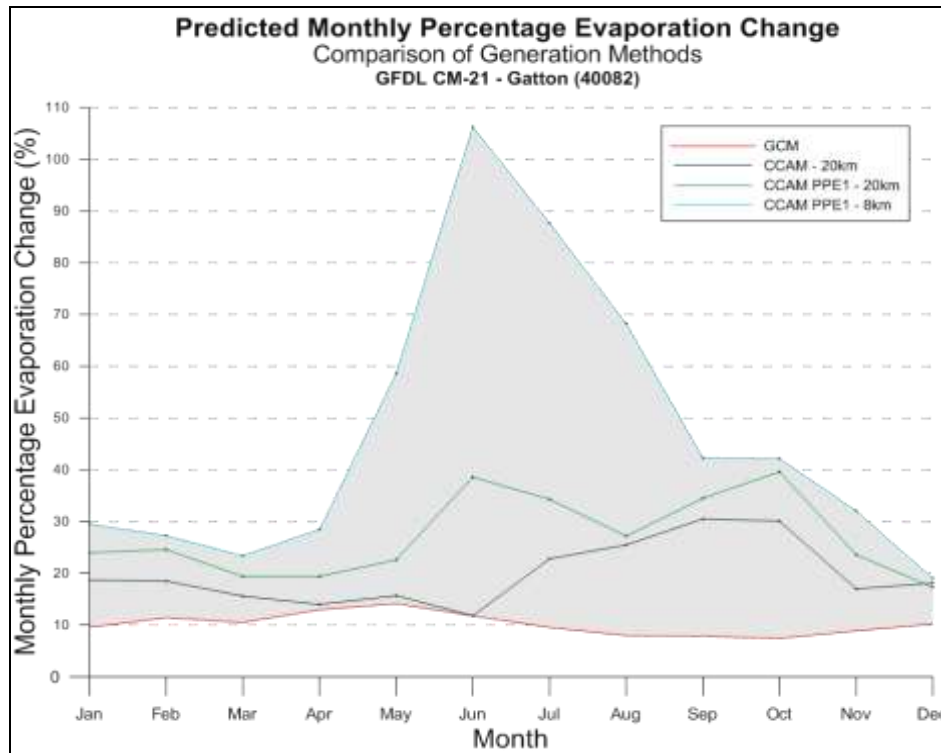


Figure 4.9. Generation method variation of projected monthly percentage evaporation change – GFDL CM-21 – Gatton (40082).

The climate model is common for all generation methods (GFDL CM21), which implies that the cause of factor difference between the various methods is due to the process of downscaling. This raises questions about the validity and accuracy of downscaling. A comparison between the factors for 8km CCAM PPE1 and 20km CCAM PPE1 shows that the magnitude and even the sign of the projected rainfall change is different for many of the months (Figure 4.8). The projected evaporation change increases in all months for both cases, but there are still some significant differences in the magnitude of projected change (Figure 4.9). The only difference between these two generation methods (8km CCAM PPE1 and 20km CCAM PPE1) is the grid size. It is generally expected that the smaller the downsized grid, the more accurate the climate change projections. The smaller grid size allows for a better representation of topographic features and local weather characteristics. It is preferable to use the smaller downsized grid for the aforementioned reasons, however the differences in projections caused some concern. Therefore, the significant differences between the two downscaled methods (CCAM PPE1 8km and 20km) was investigated to determine whether it was reasonable to use the 8km downscaled factors.

Due to the unanticipated results obtained from the 8km CCAM PPE1 generation method, it was thought that there might be an issue with the downscaling method or program. Another Perturbed Physics Experiment (PPE2) was carried out for the 20km and 8km downscaling cases to determine whether the downscaled results from PPE1 were reliable (see Table 4.6 for a description of the relevant generation methods).

Table 4.6. Description of Relevant Generation Methods.

Generation Method	Grid Size	Description
CCAM PPE1	~ 8km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 8km.
CCAM PPE1	~20km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 20km.
CCAM PPE2	~ 8km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with other changes to uncertainty physical parameters (Perturbed Physics Experiment 2 (PPE2)) – downscaled to 8km.
CCAM PPE2	~20km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with other changes to uncertainty physical parameters (Perturbed Physics Experiment 2 (PPE2)) – downscaled to 8km.

The results from the PPE2 generation method, showed very similar results to the PPE1 climate change projections. A comparison of the projected monthly rainfall and evaporation change for the PPE1 and PPE2 8km and 20km downscaled methods are shown in Figure 4.10 and Figure 4.11 respectively. As can be observed in the figures, the PPE2 8km downscaled method projects a significant decrease in rainfall and increase in evaporation in June, similar to the PPE1 8km method. The results of the PPE2 8km downscaling show the same pattern and similar magnitude of change for both rainfall and evaporation when compared to PPE1 8km. This suggests that the model results were not influenced by initial conditions causing model instabilities, but the validity and accuracy of the projections cannot be proven without further investigation. The five other focus subcatchments show similar projected rainfall change results to those presented for subcatchment UB7 (Figure 4.10). Plots for the other subareas can be found in Appendix C – Section C4.

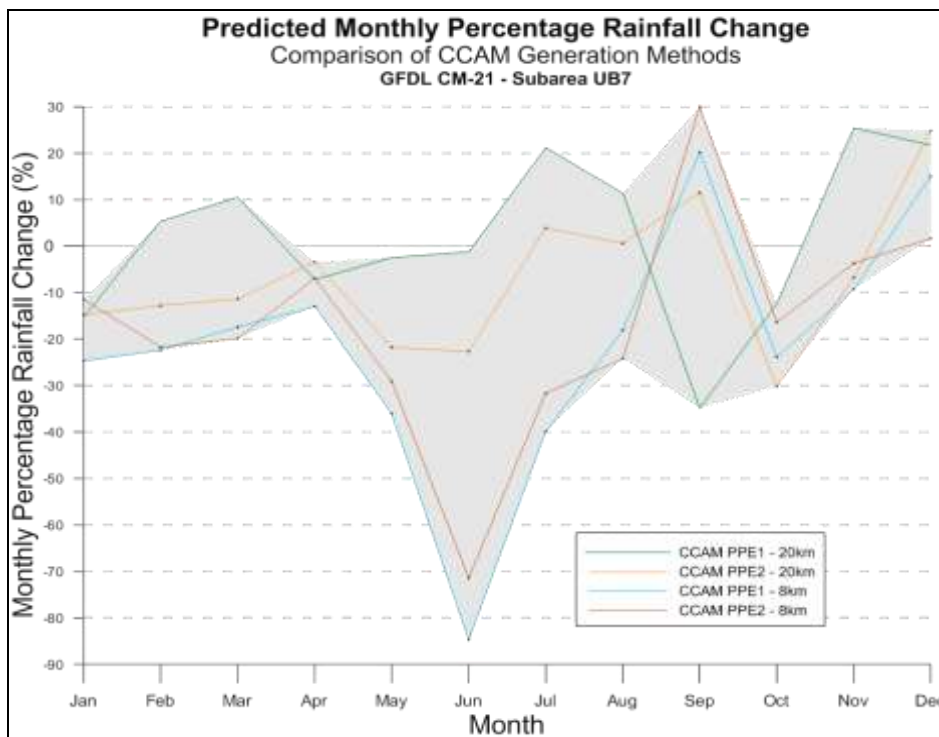


Figure 4.10. CCAM generation method variation of projected monthly percentage rainfall change – GFDL CM-21 – Subarea UB7.

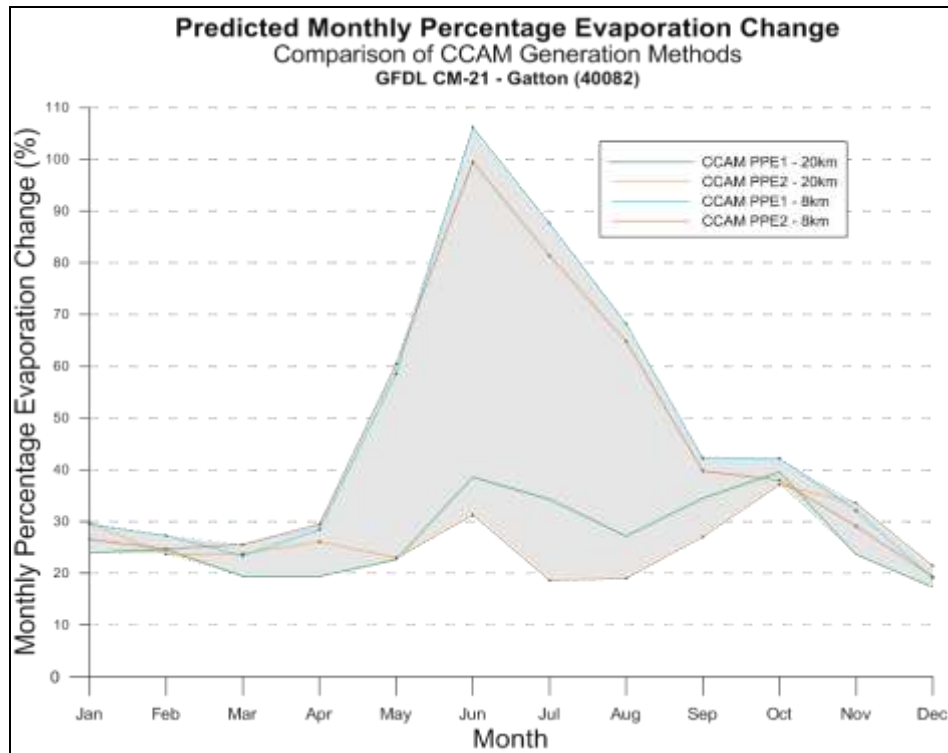


Figure 4.11. CCAM generation method variation of projected monthly percentage evaporation change – GFDL CM-21 – Gatton (40082).

4.3.3.2 IQQM Rainfall Data

The final monthly projected climate change factors for the various climate models and generation methods are applied to the daily rainfall data in the IQQM model. The mean monthly rainfall under the differing climate models and generation methods (see Table 4.7) was compared to the historical rainfall for the focus subcatchments.

Table 4.7. Description of Relevant Generation Methods.

Generation Method	Grid size	Description
GCM	Ranging from 100 to 400km	Global circulation models developed by various research institutes around the world.
CCAM	~20km	Original dynamically downscaled models using the Conformal-Cubic Atmospheric Model (CCAM) – downscaled to 20km.
CCAM PPE1	~ 8km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 8km.
CCAM PPE1	~20km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 20km.

The projected mean monthly rainfall for the 11 climate models under the GCM generation method for subcatchment UB7 are shown in Figure 4.12. This figure shows that, in this subcatchment, in the drier months of the year (April to October), the majority of the climate models project a decrease in mean monthly rainfall (compared to the historical rainfall). In the wetter months, particularly January and February, most of the climate models project an increase in mean monthly rainfall. GFDL CM21 generally has the lowest projected mean monthly rainfall. The largest range of model results falls in

February and December (30mm). The lowest projected mean monthly rainfall in February is 87mm/month (GFDL CM21), compared to a maximum projection of 117mm/month (MIROC 3.2 hires). The recorded historical mean rainfall for February is 99mm/month. In December, the projected mean monthly climate change rainfall ranges from 101mm/month (MPI ECHAM5 and UKMO HadCM3) to 131mm/month (MIUB ECHO G), with the historical rainfall averaging 109mm/month. The mean monthly rainfall plots of the five other focus subcatchments can be found in Appendix D – Section D.1. The other subcatchments show similar results to UB7 in terms of projected mean monthly rainfall.

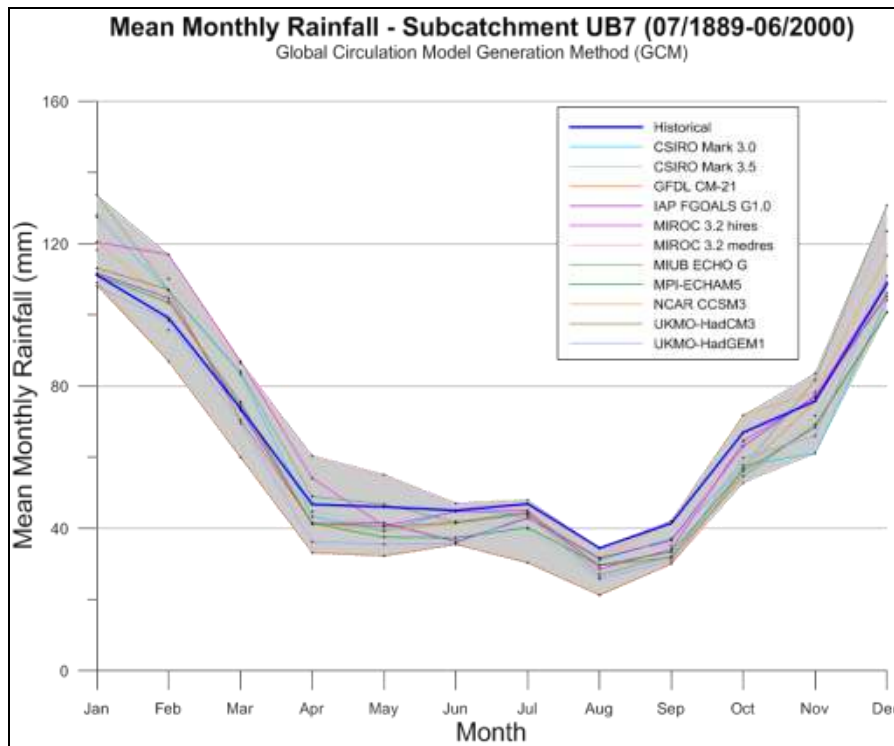


Figure 4.12. Mean monthly climate change rainfall – GCM – Subarea UB7.

The range of projected mean monthly rainfall results is much larger under the CCAM generation method compared to the GCM results. The projected rainfall results for the 12 climate models in subcatchment UB7 under CCAM are shown in Figure 4.13. The largest range of results (65mm) is in January, with the lowest projected mean monthly rainfall being 76mm/month (CSIRO Mark 3.0 A1B) and the highest being 141mm/month (MIROC 3.2 medres) (compared to a historical average of 111mm/month). As well as having a larger range of results compared to the GCM method, the CCAM generation results appear to be generally more variable. In most months, the majority of climate models project a decrease in mean monthly rainfall compared to the historical rainfall sequence. The CCAM results for the other focus subcatchments show a similar pattern to that displayed in Figure 4.13 (see Appendix D – Section D.2).

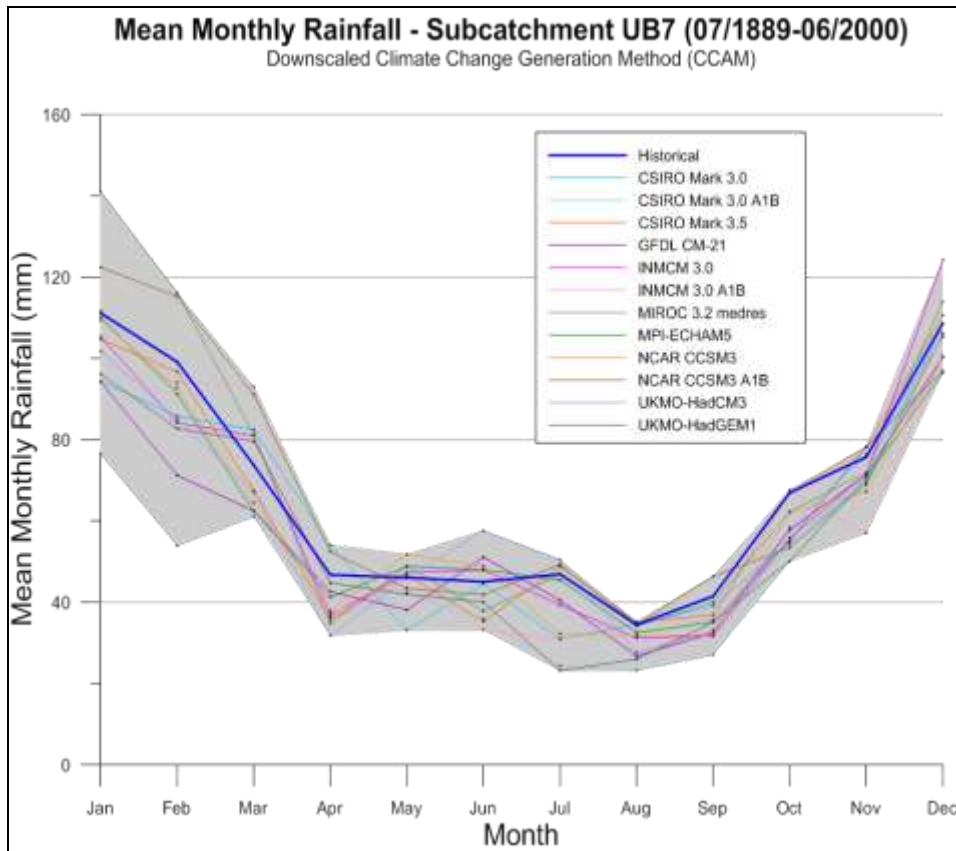


Figure 4.13. Mean monthly climate change rainfall – CCAM– Subarea UB7.

A comparison between the generation methods for mean monthly rainfall under GFDL CM21 for subcatchment UB7 can be found in Figure 4.14. The figure shows that nearly all generation methods project a decrease in mean monthly rainfall for most months under GFDL CM21. The 8km downscaled case (CCAM PPE1 8km) in particular shows a significant projected decrease in June. This is a direct result of the monthly change factors discussed above (see Figure 4.8) which shows that the 8km downscaled model projects an ~85% decrease in June rainfall under GFDL CM21. Figure 4.14 shows that there is quite a bit of variation between mean monthly rainfall projections under the various generation methods. The other subcatchments show similar variation between four generation methods under GFDL CM21 (see Appendix D – Section D.3.2). Comparisons between the projected mean monthly rainfall for the GCM and CCAM generation methods under the eight common climate models and for the six focus subcatchments can be found in Appendix D – Section D.3.1.

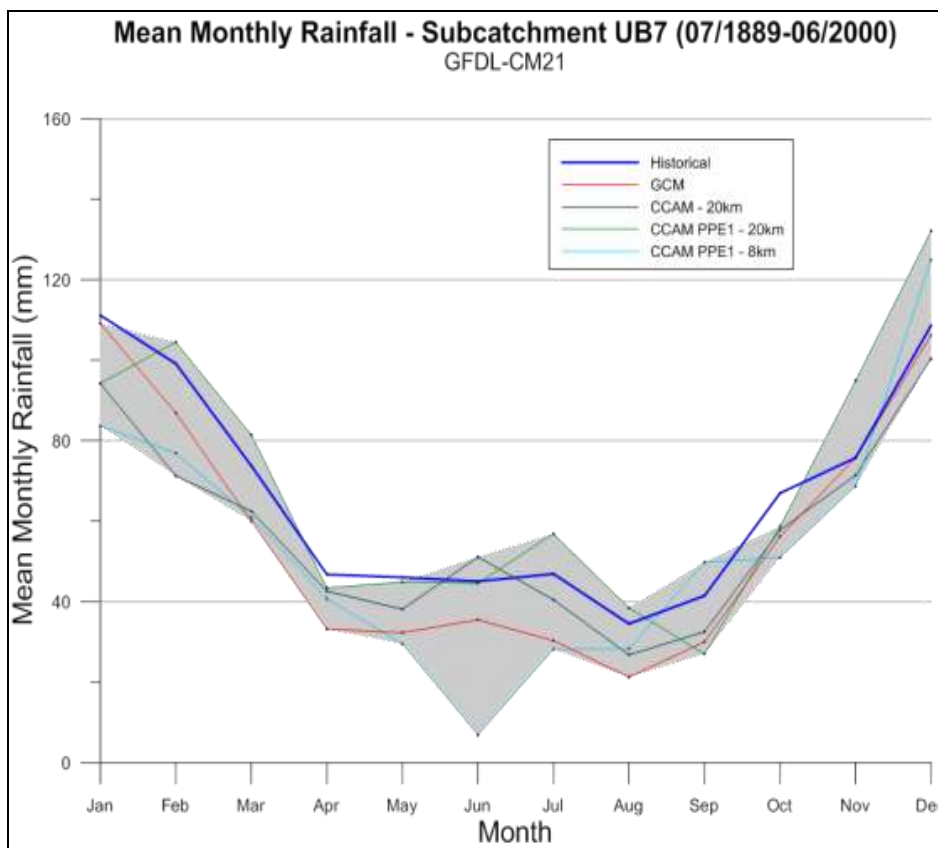


Figure 4.14. Mean monthly climate change rainfall – comparison of generation methods for GFDL-CM21 (GCM, CCAM and CCAM PPE1) – Subarea UB7.

4.3.3.3 IQQM Evaporation Data

The final monthly projected climate change factors for the various climate models and generation methods are applied to the daily evaporation data in the IQQM model. The mean monthly evaporation under the differing climate models and generation methods (see Table 4.8) was compared to the historical evaporation at Gatton (40082).

Table 4.8. Description of Relevant Generation Methods.

Generation Method	Grid Size	Description
GCM	Ranging from 100 to 400km	Global circulation models developed by various research institutes around the world.
CCAM	~20km	Original dynamically downscaled models using the Conformal-Cubic Atmospheric Model (CCAM) – downscaled to 20km.
CCAM PPE1	~ 8km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 8km.
CCAM PPE1	~20km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 20km.

The projected mean monthly evaporation for the 11 climate models under the GCM generation method at Gatton (40082) are shown in Figure 4.12. This figure shows that all of the climate models project an increase in the mean monthly evaporation for every month of the year (compared to the historical evaporation). This is a direct reflection of the projected evaporation change factors discussed above (see Figure 4.6). The highest projected mean monthly evaporation is under the CSIRO Mark 3.0

climate model. The MIUB ECHO G climate model has the lowest projected mean monthly evaporation, but still projects an increase compared to historical evaporation. The largest range of GCM model results falls in December (25mm). The lowest projected mean evaporation in December is 230.5mm (MIUB ECHO G), compared to a maximum of 255.5 (CSIRO Mark 3.0). The historical mean evaporation for December is 226mm.

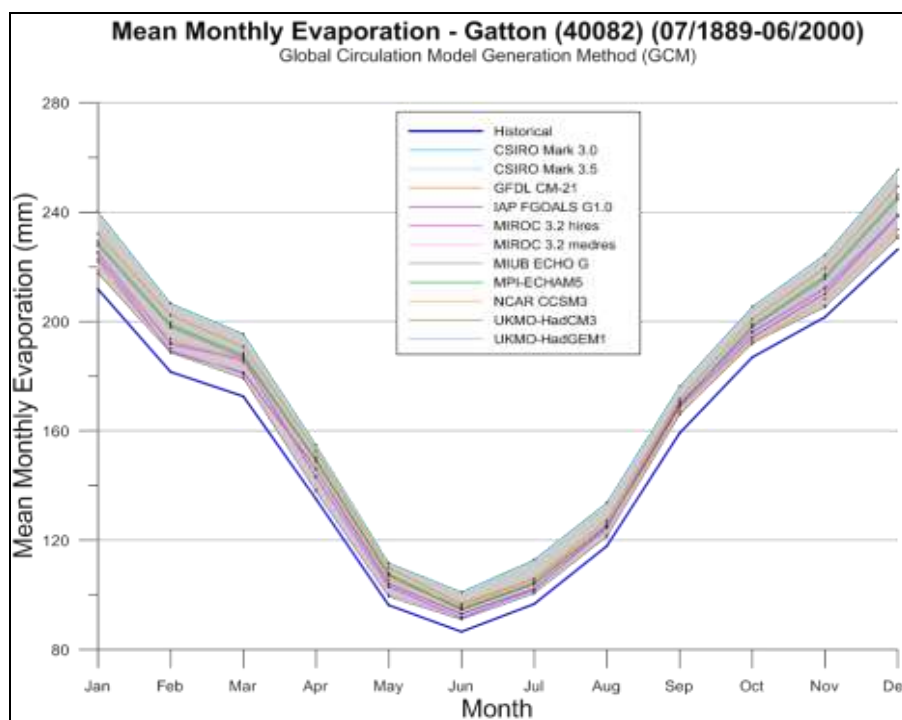


Figure 4.15. Mean monthly climate change evaporation – GCM – Gatton (40082).

There is more variation between the projected mean monthly evaporation results under the CCAM generation method compared to the GCM results. The projected evaporation results for the 12 climate models at Gatton (40082) under CCAM are shown in Figure 4.16. The largest range of results (46mm) is in October, with the lowest projected mean monthly evaporation being 197mm (NCAR CCSM3 A1B) and the highest being 243mm (GFDL CM21) (compared to a historical average of 187mm). All climate models project an increase in mean monthly evaporation compared to the historical evaporation sequence for every month.

A comparison between the generation methods for mean monthly evaporation under GFDL CM21 at Gatton (40082) can be found in Figure 4.17. The figure shows that all generation methods show a projected increase in mean monthly evaporation under GFDL CM21. The 8km downscaled case (CCAM PPE1 8km) in particular shows a significant projected increase in June compared to the other methods. This is a direct result of the monthly change factors discussed above (see Figure 4.9) which shows that the 8km downscaled model projects an ~105% increase in June evaporation under GFDL CM21. As previously mentioned, due to differences in the calculation of evaporation between the GCM and CCAM for this model, a more relevant comparison is between the ~20km and ~8km downscaled CCAM models. The extreme increase in evaporation shown in this comparison is due entirely to the increase in resolution of the downscaling. The additional perturbed physics experiment, PPE2, was conducted for both resolutions to validate the original results (see Figure 4.11).

Figure 4.17 shows that there is quite a bit of variation between mean monthly evaporation projections under the various generation methods, with the 8km downscaled method having the highest projected evaporation every month. Comparisons between the projected mean monthly evaporation for the GCM and CCAM generation methods under the eight common climate models and for the six focus subcatchments can be found in Appendix E – Section E.3.1.

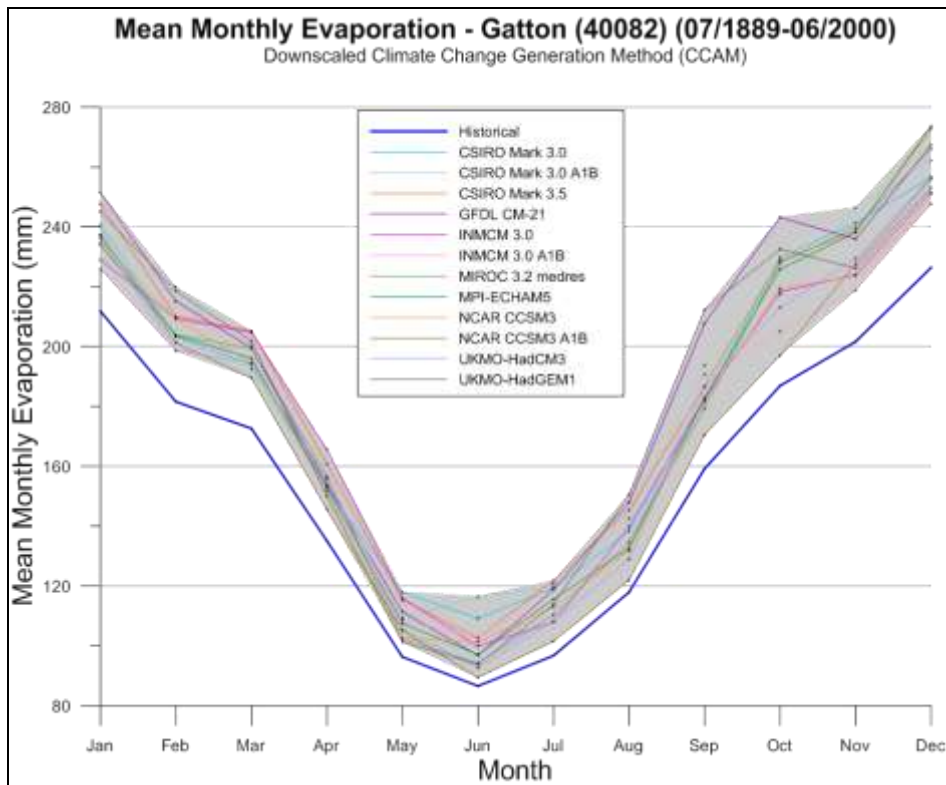


Figure 4.16. Mean monthly climate change evaporation – CCAM – Gatton (40082).

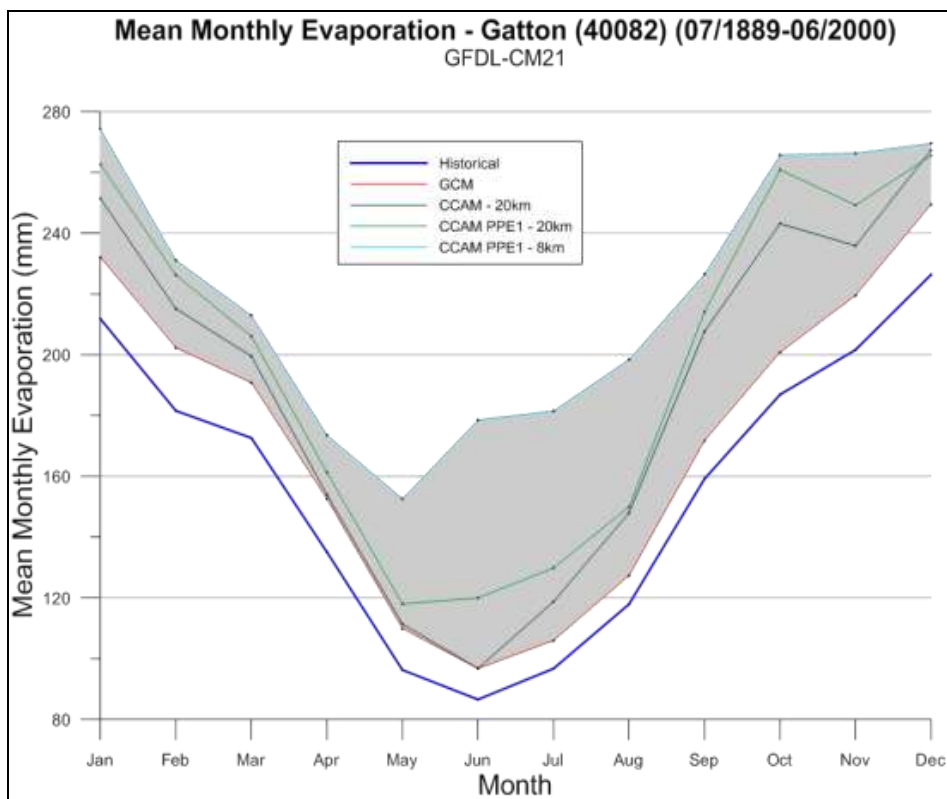


Figure 4.17. Mean monthly climate change evaporation – comparison of generation methods for GFDL-CM21 (GCM, CCAM and CCAM PPE1) – Gatton (40082).

4.3.3.4 IQQM Inflow Data

The IQQM model inflow data is generated using the climate change adjusted rainfall and evaporation data, as well as a calibrated Sacramento rainfall-runoff model. The mean monthly inflow under the differing climate models and generation methods (see Table 4.9) was compared to the historical inflow for the focus subcatchments.

Table 4.9. Description of Relevant Generation Methods.

Generation Method	Grid Size	Description
GCM	Ranging from 100 to 400km	Global circulation models developed by various research institutes around the world.
CCAM	~20km	Original dynamically downscaled models using the Conformal-Cubic Atmospheric Model (CCAM) – downscaled to 20km.
CCAM PPE1	~ 8km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 8km.
CCAM PPE1	~20km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 20km.

The projected mean monthly inflow for the 11 climate models under the GCM generation method for subcatchment UB7 are shown in Figure 4.18. Similar to the results observed for the mean monthly rainfall, this figure shows that, in this subcatchment, in the drier months, the majority of the climate models project a decrease in mean monthly inflow (compared to the historical inflow). GFDL CM21 generally has the lowest projected mean monthly inflow. The largest range of model results falls in December (418ML). The lowest projected mean monthly inflow in February is 275ML (GFDL CM21), compared to a maximum projected mean of 693ML (MIROC 3.2 hires). The historical mean inflow for February is 486ML. The mean monthly inflow plots of the five other focus subcatchments can be found in Appendix F – Section F.1. The other subcatchments show similar results to UB7 in terms of projected mean monthly inflow.

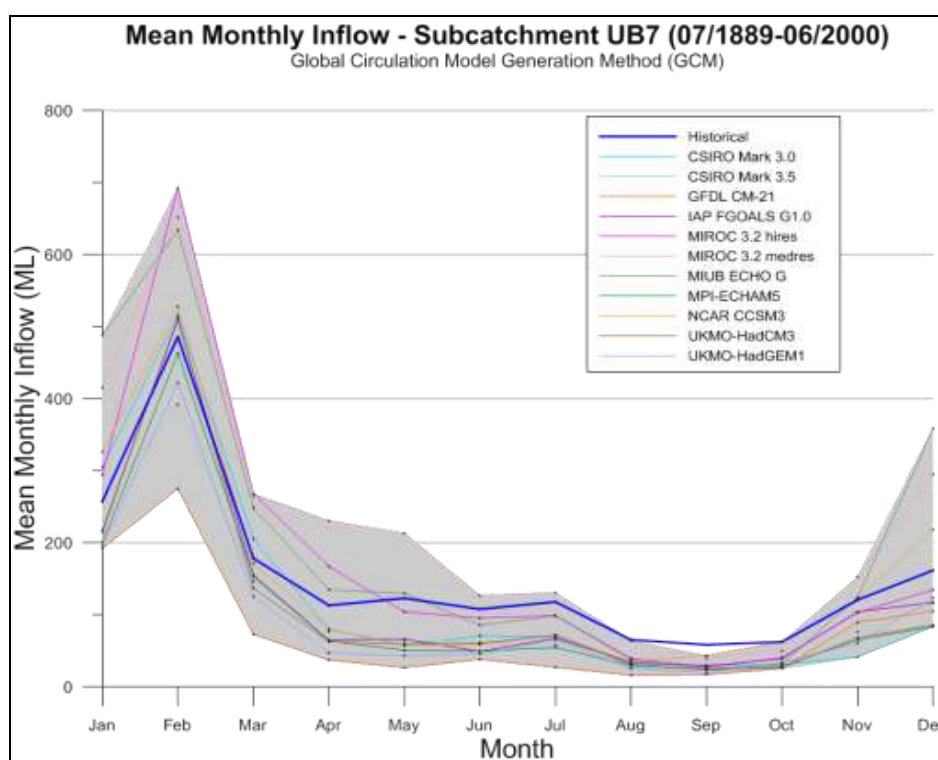


Figure 4.18. Mean monthly climate change inflow – GCM – Subarea UB7.

There is more variation between projected mean monthly inflow results under the CCAM generation method compared to the GCM results. The projected inflow results for the 12 climate models in subcatchment UB7 under CCAM are shown in Figure 4.19. The largest range of results (654ML) is in February, with the lowest projected mean monthly inflow being 40ML (CSIRO Mark 3.0 A1B) and the highest being 694ML (MIROC 3.2 medres) (compared to a historical average of 486ML). In most months, the majority of climate models project a decrease in mean monthly inflow compared to the historical inflow sequence. The CCAM results for the other focus subcatchments show a similar pattern to that displayed in Figure 4.19 (see Appendix F – Section F.2).

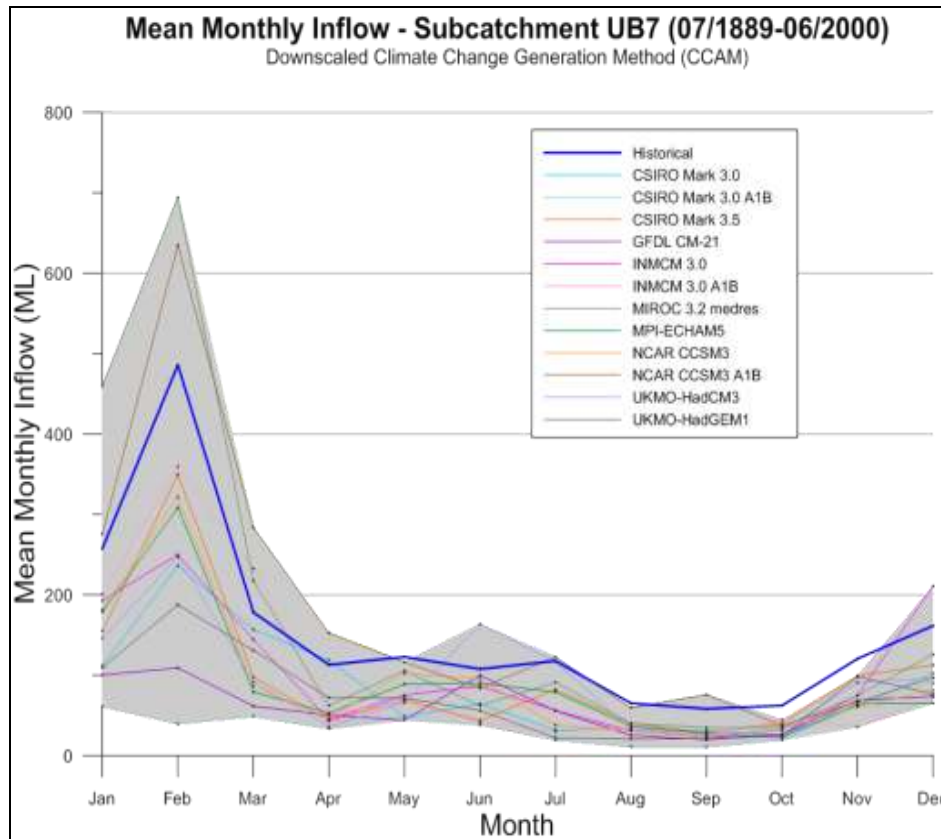


Figure 4.19. Mean monthly climate change inflow – CCAM – Subarea UB7.

A comparison between the generation methods for mean monthly inflow under GFDL CM21 for subcatchment UB7 can be found in Figure 4.20. The figure shows that the projected mean monthly inflow for nearly all generation methods is less than the historic inflow under GFDL CM21. In most months, the rainfall is projected to decrease (see Figure 4.14) and the evaporation is projected to increase (see Figure 4.17) under GFDL CM21, hence a projected decrease in inflow is to be expected. The 8km downscaled case (CCAM PPE1 8km) shows the lowest projected monthly inflow, which is a direct result of the monthly change factors applied to the rainfall and evaporation sequences as discussed above. Figure 4.20 also displays the inflow results for UB7 assuming that only evaporation is affected by climate change. For these cases, rainfall is assumed to remain the same as the historical sequence, while the evaporation is adjusted using the aforementioned monthly factors. The UB7 inflow results for the cases where rainfall is not adjusted show a very similar pattern to the historical sequence and each other. The inflow for these cases is projected to be less than the historical inflow every month (see Figure 4.17 for evaporation factors). For the generation methods with both rainfall and evaporation adjusted, there is quite a bit of variation between mean monthly inflow projections. The other subcatchments show similar results to UB7 inflow under GFDL CM21 (see Appendix F – Section F.3.2). Comparisons between the projected mean monthly inflow for the GCM and CCAM generation methods under the eight common climate models and for the six focus subcatchments can be found in Appendix F – Section F.3.1.

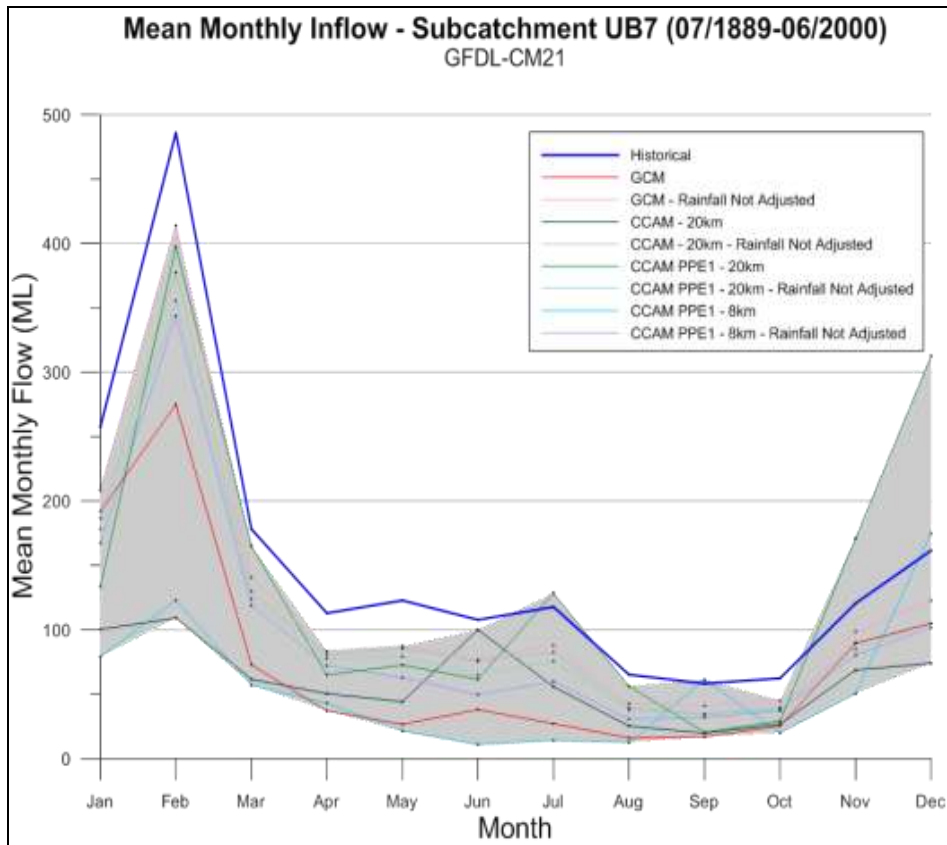


Figure 4.20. Mean monthly climate change inflow – comparison of generation methods for GFDL-CM21 (GCM, CCAM and CCAM PPE1) – Subarea UB7.

5. CLIMATE CHANGE ANALYSIS AND RESULTS

5.1. Global Circulation Model Method (GCM)

As mentioned above, 11 global circulation models were used in this study (see Table 5.1). Climate adjusted data was generated and run through the Moreton IQQM for each of the 11 GCMs. For each of the GCMs, the model was run first with both rainfall and evaporation adjusted and then with only evaporation adjusted. As discussed above, the projections of evaporation change are much more reliable and consistent for the various climate models. Hence, an assessment of the system performance with only evaporation (and inflow) adjusted for climate change was completed. It was assumed that rainfall showed no change from the historical sequences for these runs. However, it should be noted that because evaporation was not directly calculated within all of the GCMs, a relationship between temperature and evaporation was derived from the models with available data and used to estimate the evaporation change for the five the models that did not have evaporation.

Table 5.1. List of GCM Climate Models Used in this Study.

All GCM Climate Models	Evaporation Factors
CSIRO Mark 3.0 A2	Evaporation
CSIRO Mark 3.5 A2	Evaporation
GFDL CM21 A2	Temperature relationship
IAP FGOALS G1.0 A1B	Evaporation
MIROC 3.2 hires A1B	Evaporation
MIROC 3.2 medres A2	Evaporation
MIUB ECHO G A2	Temperature relationship
MPI ECHAM5 A2	Temperature relationship
NCAR CCSM3 A2	Evaporation
UKMO HadCM3 A2	Temperature relationship
UKMO HadGEM1 A2	Temperature relationship

5.1.1. Rainfall and Evaporation Climate Change Adjusted

The 11 GCM model runs for the cases where both rainfall and evaporation are adjusted generate a significant range of results. As can be observed in Figure 5.1, there is quite a variation in simulated storage volume between the historical and GCM results. While Figure 5.1 gives a good indication of the performance of the storage over the whole simulation period, the differences between climate model results can be observed more clearly in Figure 5.2 (showing a 30-year period of the simulation period).

From Figure 5.2, it can be noted that GFDL CM21 appears to be the driest of the 11 GCMs, with it performing the worst in terms of simulated storage volume. For the period shown in the plot (1900 – 1930), the combined simulated storage volume for GFDL CM21 is low and often close to empty. It has extended dry periods compared to the other GCMs and also requires a more significant event to recover from a dry spell. This is a direct result of the climate change adjusted data described in Section 4.3. GFDL CM21 had generally the lowest projected mean monthly rainfall, along with being one of the highest in projected evaporation. The combination of low rainfall and high evaporation results in very poor storage performance compared to the historical case and other GCMs.

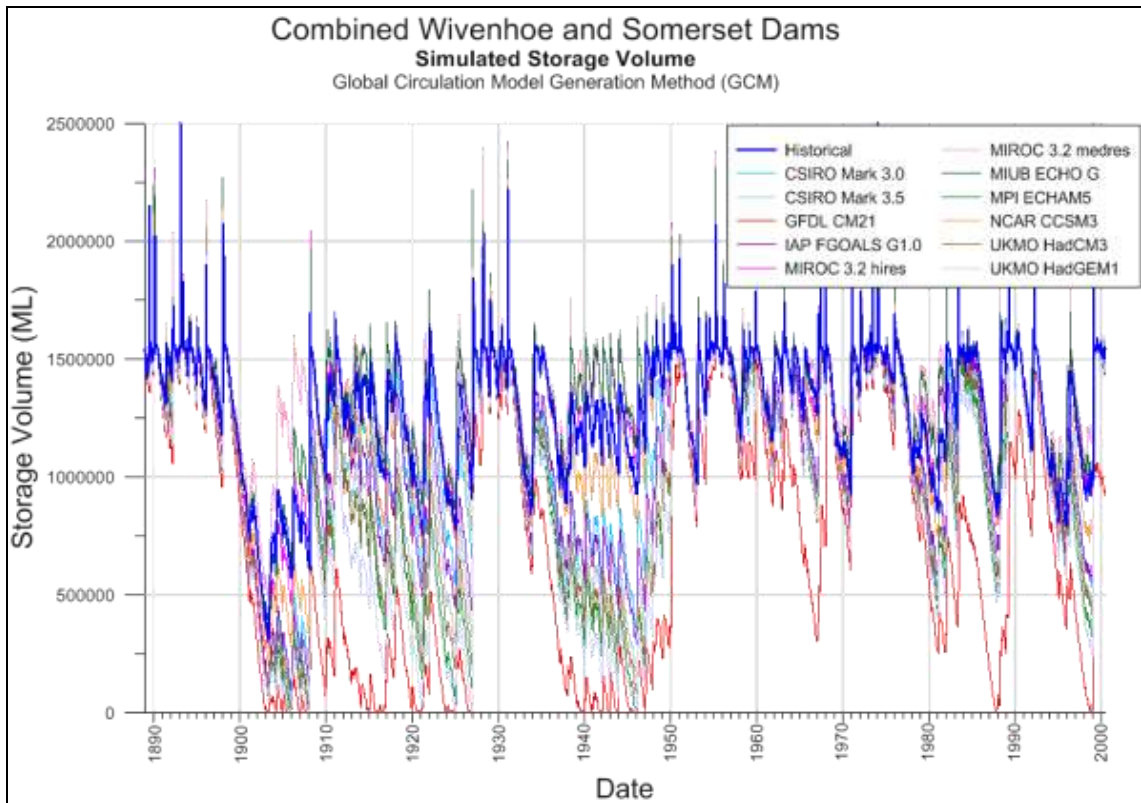


Figure 5.1. Combined Wivenhoe and Somerset Dam Simulated Storage Volume – Historical and GCM Climate Models.

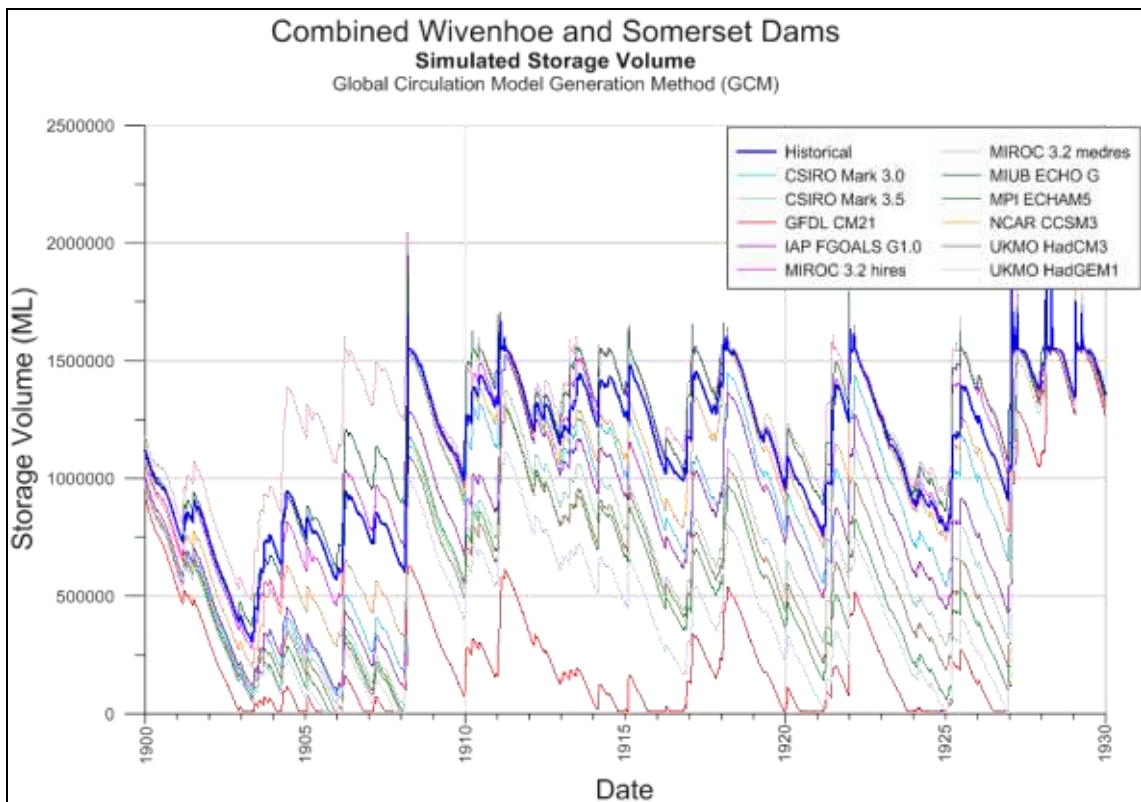


Figure 5.2. Combined Wivenhoe and Somerset Dam Simulated Storage Volume (1900-1930) – Historical and GCM Climate Models.

The models which demonstrated the best simulated storage performance were MIROC 3.2 medres and MIUB ECHO G. Both of those GCMs show a higher simulated storage volume compared to the historical case for the majority of the simulation period. Both MIROC 3.2 medres and MIUB ECHO G project an increase in mean monthly rainfall in the summer months (compared to historical) and a projected increase in evaporation which is not as extreme as the other GCMs (see Section 4.3). On the 01/01/1910, the historical simulated storage volume is 1,159,700ML (~75% of full supply volume (FSV)), compared to the minimum projected storage volume of 204,050ML (~13% of FSV) (GFDL CM21) and the maximum projected volume of 1,267,600ML (~82% of FSV) (MIROC 3.2 medres).

For the majority of the simulation period, the range of model result spans from a higher storage volume to a significantly lower simulated storage volume compared to the historical case. This range can be seen clearly in Figure 5.3 which shows the historical case, as well as a band of results for the 11 climate models.

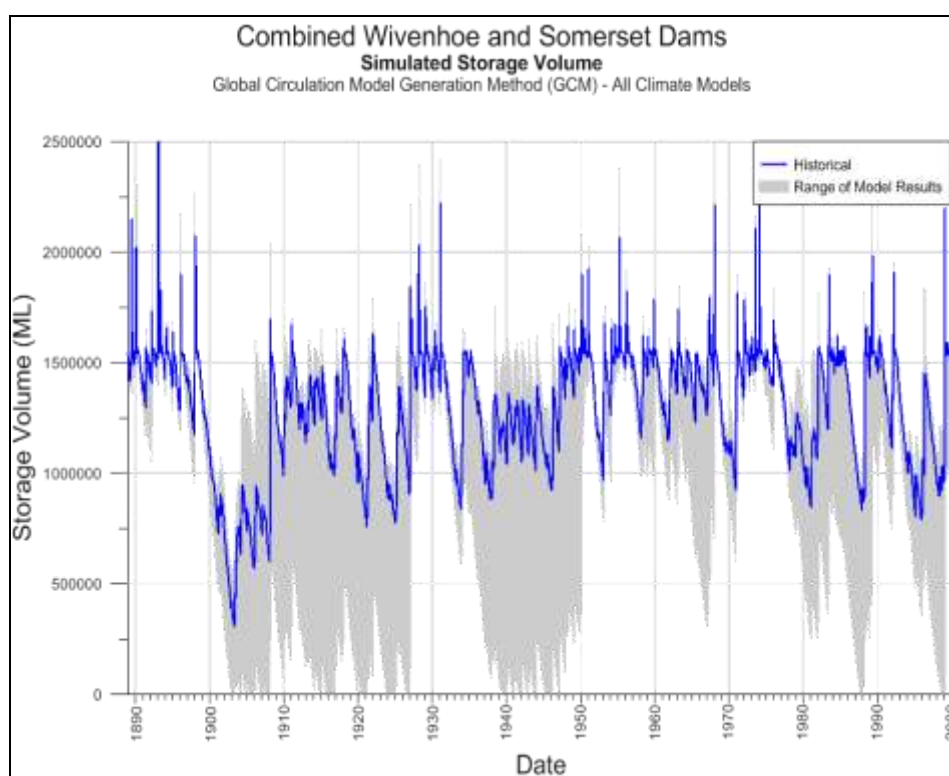


Figure 5.3. Combined Wivenhoe and Somerset Dam Simulated Storage Volume – Historical and Range of GCM Climate Model Results.

As expected, the mean monthly end of system flow for the Moreton model shows similar results as that described for the storage behaviour (see Figure 5.4). MIROC 3.2 medres generally has the largest mean monthly flow at the end of the system, with GFDL CM21 having the lowest. In March for example, the mean monthly end of system flow projected by MIROC 3.2 medres is 303,469ML which is ~158% of the historical mean monthly end of system flow for the same month. GFDL CM21 on the other hand, projects an end of system flow of 77,828ML which is ~41% of the historical equivalent.

The range of model results demonstrates the uncertainty in climate change projections and difficulty in planning for climate change.

See Appendix G – Section G.1 for all GCM storage plots and Appendix H – Section H.1 for GCM end of system flow plots.

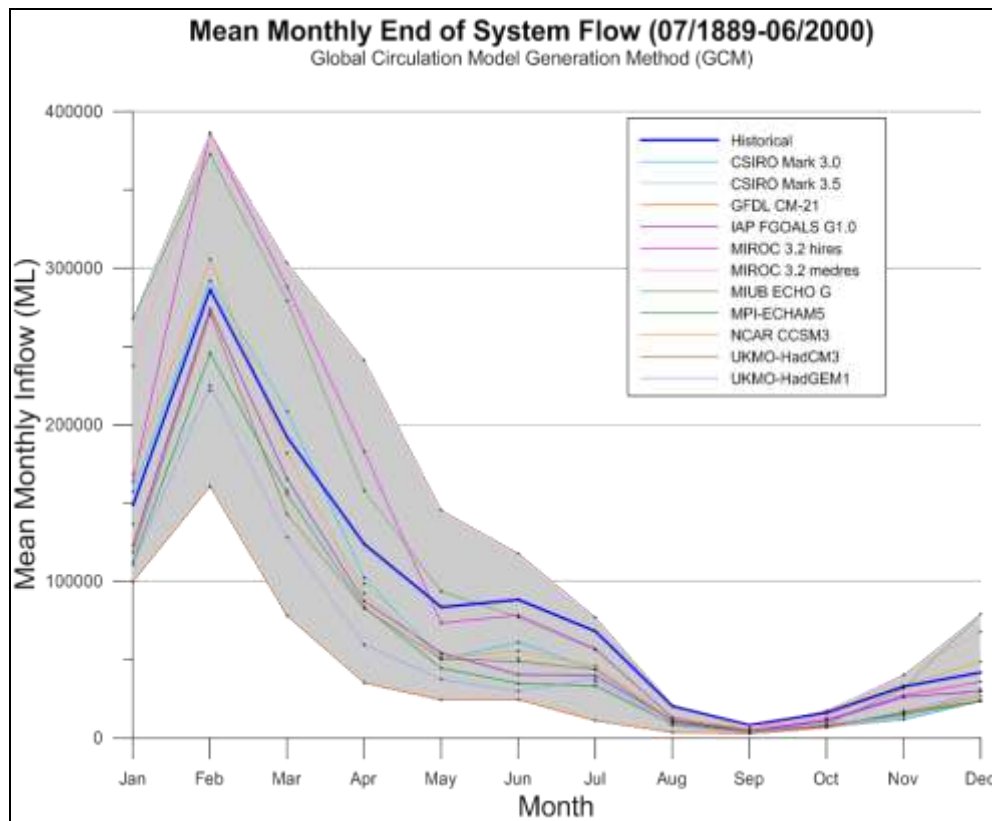


Figure 5.4. Mean Monthly End of System Flow (Node 360) – Historical and Range of GCM Climate Model Results.

5.1.2. Only Evaporation Climate Change Adjusted

An assessment of the system with only the evaporation adjusted for climate change was also completed for the GCMs. The Moreton IQQM was re-run for each of the 11 GCMs assuming no change to rainfall from historical and evaporation change based on the factors described in Section 4.3. As the projected evaporation change is relatively consistent for the various climate models, the range of results is significantly smaller than that described above in Section 5.1.1 (see Figure 5.5 and Figure 5.7). All of the GCMs project an increase in evaporation; hence the simulated storage volume for each of the GCMs is less than the historical case.

Figure 5.6 shows the comparisons between the simulated storage volume for the historical and GCM cases more clearly for the period from 1900 to 1930. It can be observed from Figure 5.6 that the CSIRO Mark 3.0 GCM has the lowest projected simulated storage volume, while MIUB ECHO G has a projected storage volume closest to the historical case. Evaporation is the only feature being adjusted in these cases, and hence the spread of the GCM results is a direct consequence of the evaporation factors described above (Section 4.3). The reduced range of storage volume results is also more clear and noticeable in Figure 5.6, particularly compared to the plot for the same period of the storage volume results when both rainfall and evaporation were adjusted for climate change (Figure 5.2). For example, on the 01/01/1910 the historical simulated storage volume is 1,159,700ML (~75% of FSV), compared to the minimum projected storage volume of 710,290ML (~46% of FSV) (CSIRO Mark 3.0) and the maximum projected volume of 1,113,300ML (~72% of FSV) (MIUB ECHO G).

The reduced range of the model results (compared to the range described in Section 5.1.1) shows that there is much better agreement between the various GCMs in terms of projected evaporation change. See Appendix G – Section G.1 for all GCM storage plots and Appendix H – Section H.1 for GCM end of system flow plots.

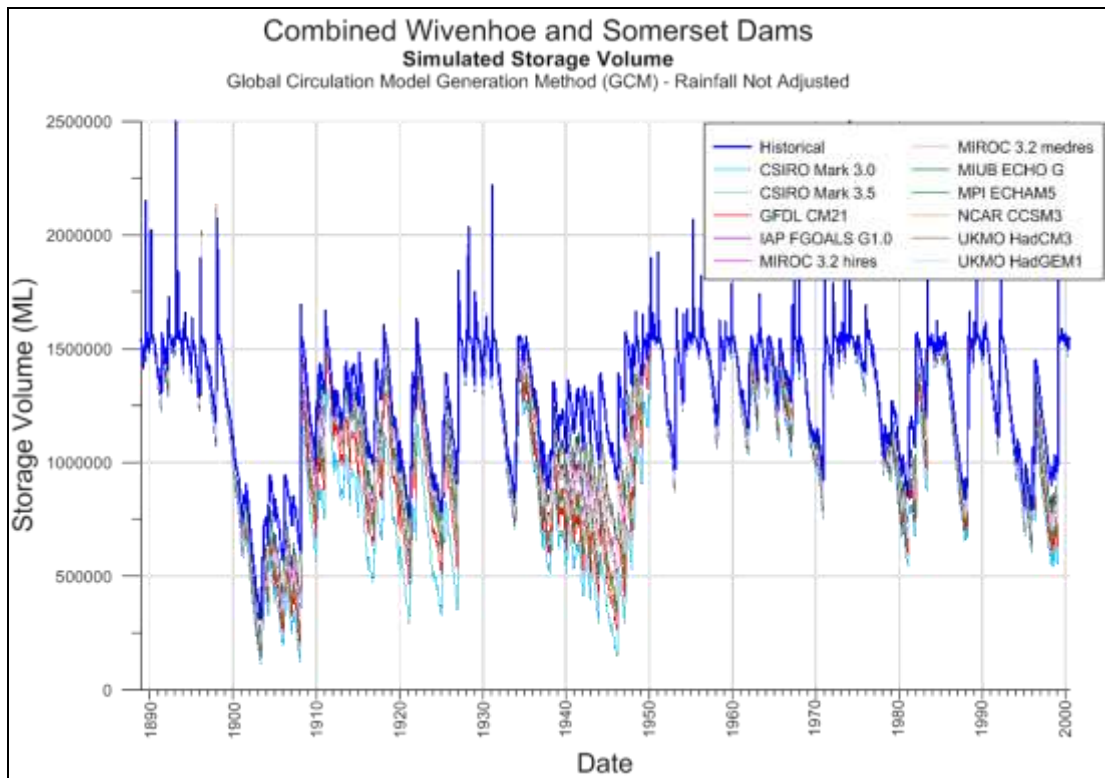


Figure 5.5. Combined Wivenhoe and Somerset Dam Simulated Storage Volume – Historical and GCM Climate Models (Rainfall Not Adjusted).

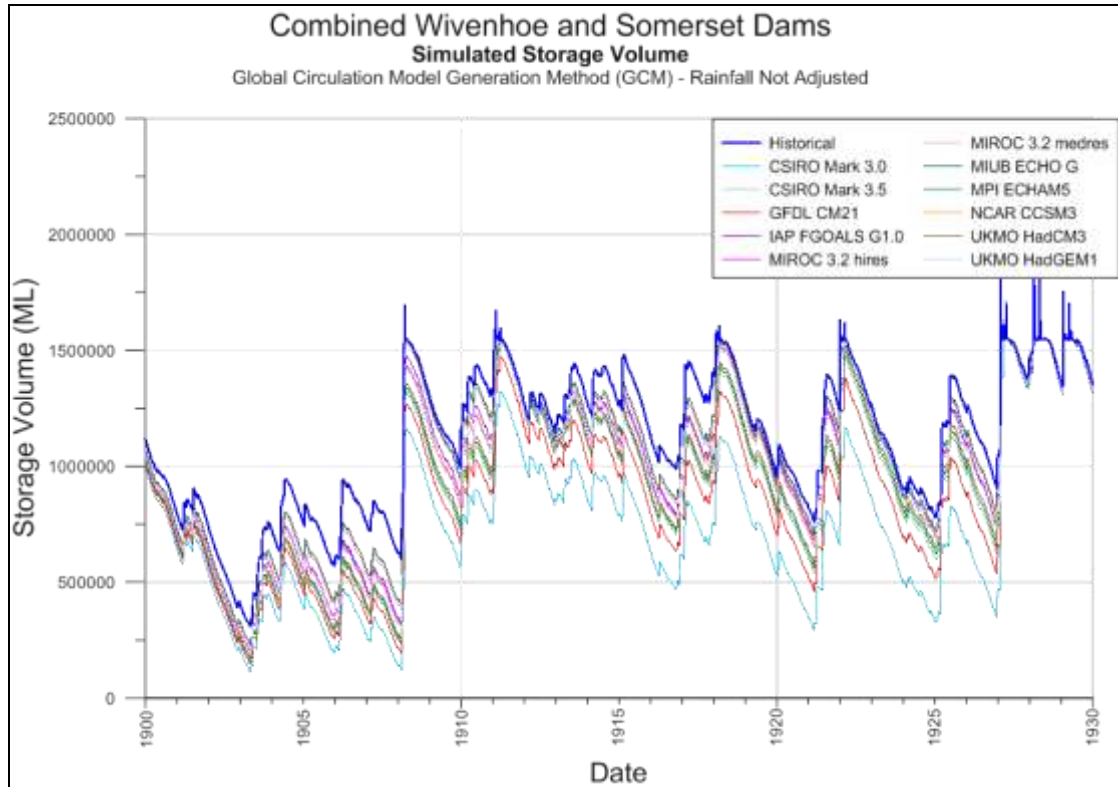


Figure 5.6. Combined Wivenhoe and Somerset Dam Simulated Storage Volume (1900-1930) – Historical and GCM Climate Models (Rainfall Not Adjusted).

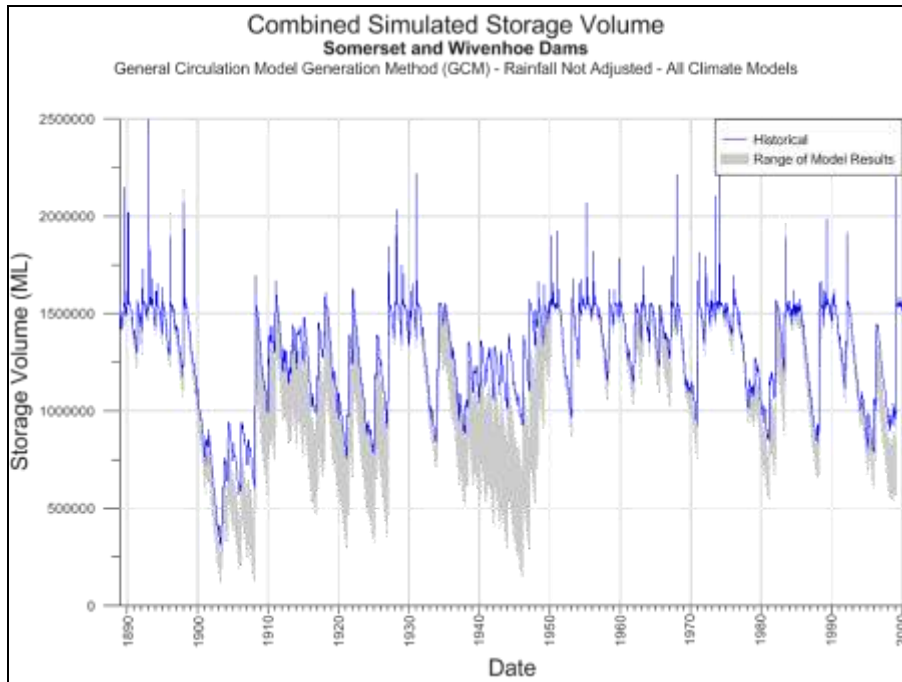


Figure 5.7. Combined Wivenhoe and Somerset Dam Simulated Storage Volume – Historical and Range of GCM Climate Model Results (Rainfall Not Adjusted).

As expected for these runs, the mean monthly end of system flow for the Moreton model shows similar results as those described for the storage behaviour (see Figure 5.8). The range of model results in terms of end of system flow is quite small and each of the cases projects a mean monthly flow of less than the historical case. MIUB ECHO G generally has the largest mean monthly flow at the end of the system, with CSIRO Mark 3.0 having the lowest. In March for example, the mean monthly end of system flow projected by MIUB ECHO G is 172,823ML which is ~90% of the historical mean monthly end of system flow for the same month. CSIRO Mark 3.0 on the other hand, projects an end of system flow of 145,811ML which is ~76% of the historical equivalent.

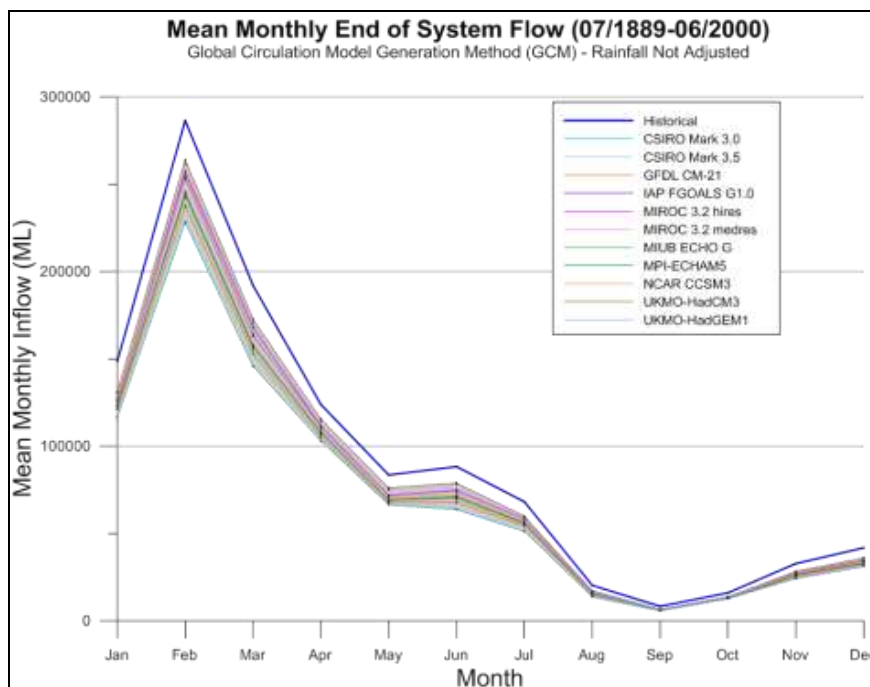


Figure 5.8. Mean Monthly End of System Flow (Node 360) – Historical and Range of GCM Climate Model Results (Rainfall Not Adjusted).

5.2. Dynamically Downscaled Method (CCAM)

A total of 12 dynamically downscaled models were used in this study (see Table 5.2). Climate adjusted data was generated and run through the Moreton IQQM for each of the 12 CCAM models. Using the same process and methods outlined in Section 5.1 for the GCMs, for each of the downscaled models, the IQQM was run first with both rainfall and evaporation adjusted and then with only evaporation adjusted. As discussed above, the projections for evaporation change are much more reliable and consistent across the various climate models. Hence, an assessment of the system performance with only evaporation (and therefore also the flow) adjusted for climate change was completed. It was assumed that rainfall showed no change from the historical sequences for these runs.

Table 5.2. List of Dynamically Downscaled (CCAM) Climate Models Used in this Study.

All Dynamically Downscaled (CCAM) Climate Models
CSIRO Mark 3.0 A2
CSIRO Mark 3.0 A1B
CSIRO Mark 3.5 A2
GFDL CM21 A2
INMCM 3.0 A2
INMCM 3.0 A1B
MIROC 3.2 medres A2
MPI ECHAM5 A2
NCAR CCSM3 A2
NCAR CCSM3 A1B
UKMO HadCM3 A2
UKMO HadGEM1 A2

5.2.1. Rainfall and Evaporation Climate Change Adjusted

The 12 CCAM model runs for the cases where both rainfall and evaporation are adjusted generate a significant range of results. As can be observed in Figure 5.9, there is quite a variation in simulated storage volume between the historical and CCAM results. Similar to the GCM results, for most of the simulation period the range of model result spans from a higher storage volume to a significantly lower simulated storage volume compared to the historical case. This range can be seen clearly in Figure 5.11 which shows the historical case, as well as a band of results for the 12 climate models.

While Figure 5.9 gives a good indication of the performance of the storage over the whole simulation period, the differences between climate model results can be observed more clearly in Figure 5.10 (zoomed to a 30-year period of the simulation period from 1900 to 1930). From the zoomed plot (Figure 5.10), it can be noted that CSIRO Mark 3.0 A1B appears to be the driest of the 12 CCAM models, with it performing the worst in terms of simulated storage volume. For the period shown in the plot (1900 – 1930), the combined simulated storage volume for CSIRO Mark 3.0 A1B and GFDL CM21 are low and often close to empty. It has extended dry periods compared to the other CCAM results and they also require a more significant event to recover from a dry spell. This is a direct result of the climate change adjusted data described in Section 4.3. CSIRO Mark 3.0 A1B has generally low projected mean monthly rainfall, along with high projected evaporation. The combination of low rainfall and high evaporation results in very poor storage performance compared to the historical case and other CCAM models.

The model which demonstrated the best simulated storage performance was NCAR CCSM3 A1B. This CCAM model showed a higher simulated storage volume compared to the historical case for a lot of the simulation period. NCAR CCSM3 A1B project an increase in mean monthly rainfall in the

summer months (compared to the historical) and a projected increase in evaporation which is not as extreme as the other CCAM models for most months (see Section 4.3). On the 01/01/1910 the historical simulated storage volume is 1,159,700ML (~75% of full supply volume (FSV)), compared to the minimum projected storage volume of 200,880ML (~13% of FSV) (CSIRO Mark 3.0 A1B) and the maximum projected volume of 1,098,400ML (~71% of FSV) (NCAR CCSM3 A1B).

As expected, the mean monthly end of system flow for the Moreton model shows similar results as that described for the storage behaviour (see Figure 5.12). NCAR CCSM3 A1B generally has the largest mean monthly flow at the end of the system, with CSIRO Mark 3.0 A1B having the lowest. In February for example, the mean monthly end of system flow projected by NCAR CCSM3 A1B is 371,672ML which is ~130% of the historical mean monthly end of system flow for the same month. CSIRO Mark 3.0 A1B on the other hand, projects an end of system flow of 83,470ML which is ~29% of the historical equivalent.

As mentioned for the GCM results, the range of model results demonstrates the uncertainty in climate change projections and difficulty in planning for climate change.

See Appendix G – Section G.2 for all CCAM storage plots and Appendix H – Section H.2 for CCAM end of system flow plots.

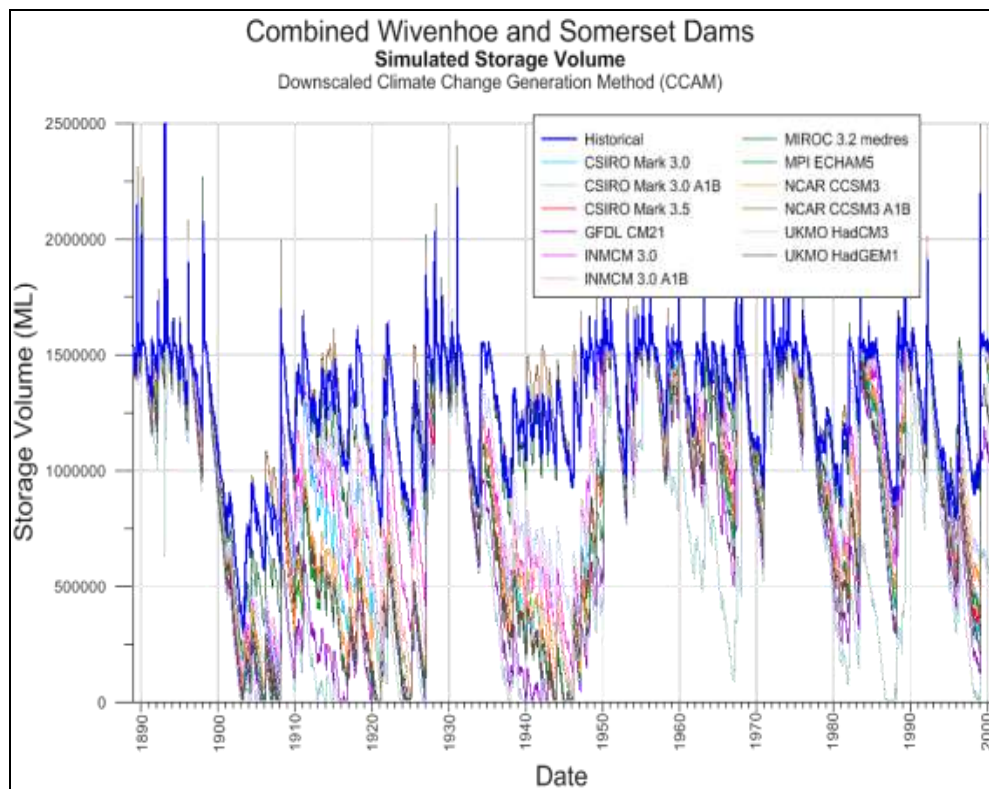


Figure 5.9. Combined Wivenhoe and Somerset Dam Simulated Storage Volume – Historical and CCAM Climate Models.

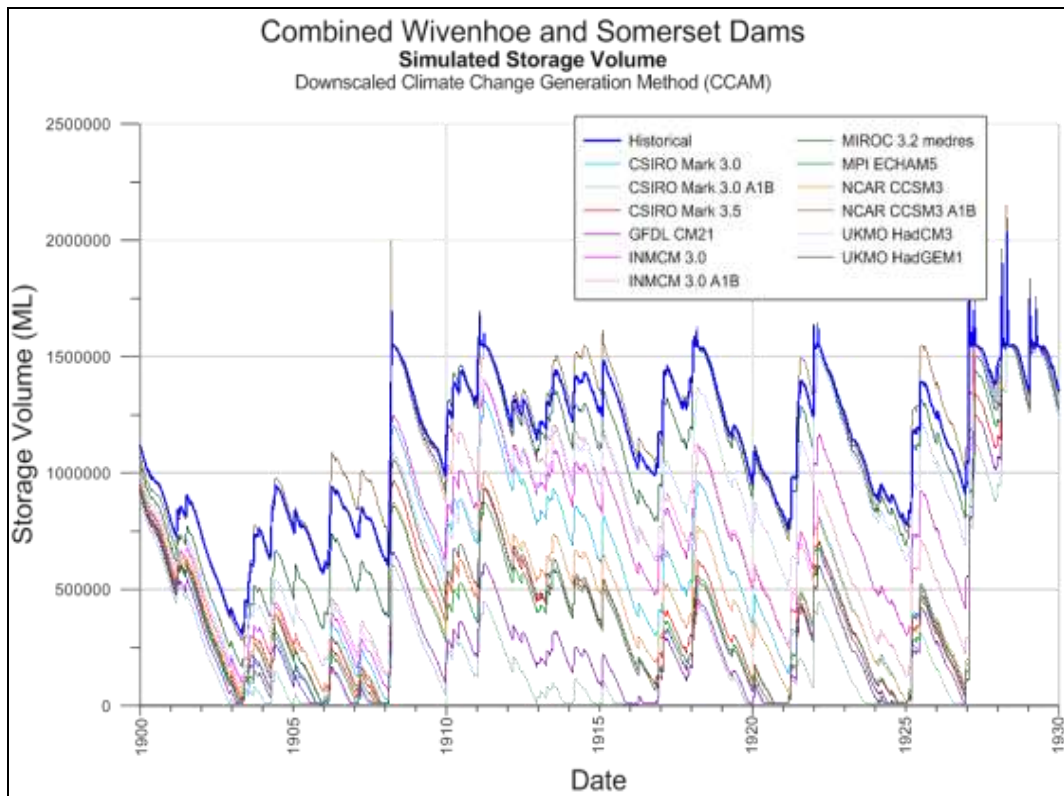


Figure 5.10. Combined Wivenhoe and Somerset Dam Simulated Storage Volume 1900-1930 – Historical and CCAM Climate Models.

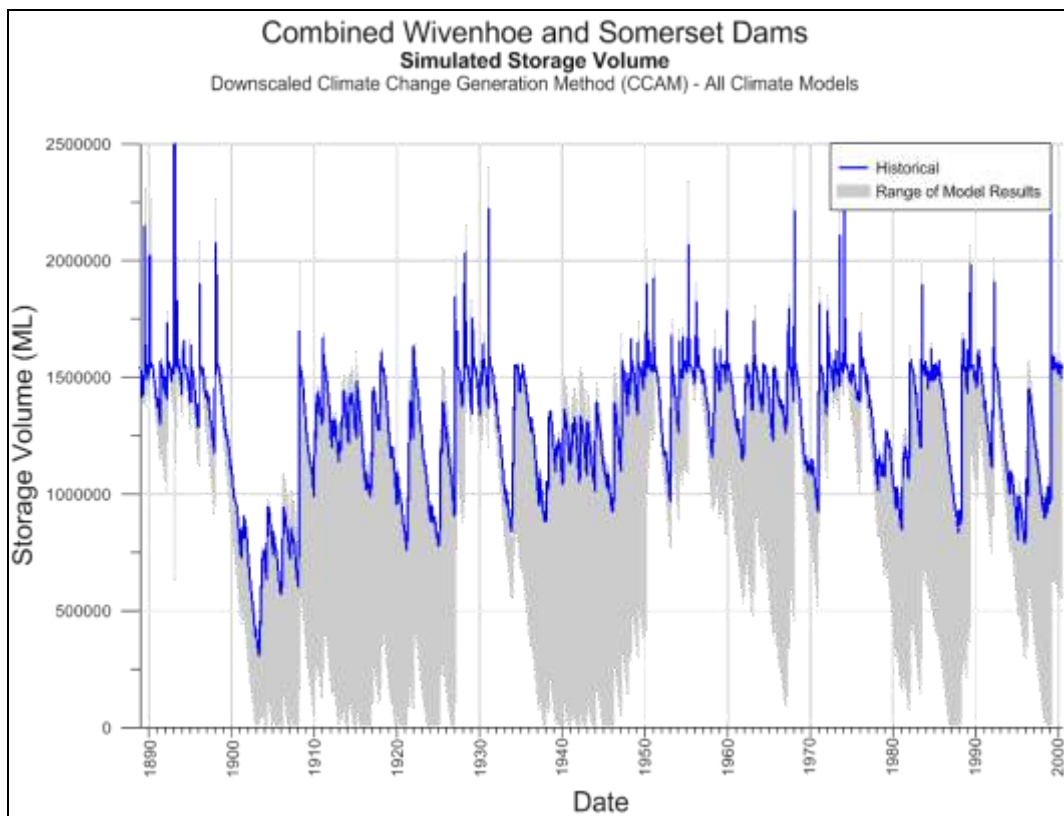


Figure 5.11. Combined Wivenhoe and Somerset Dam Simulated Storage Volume – Historical and Range of CCAM Climate Model Results.

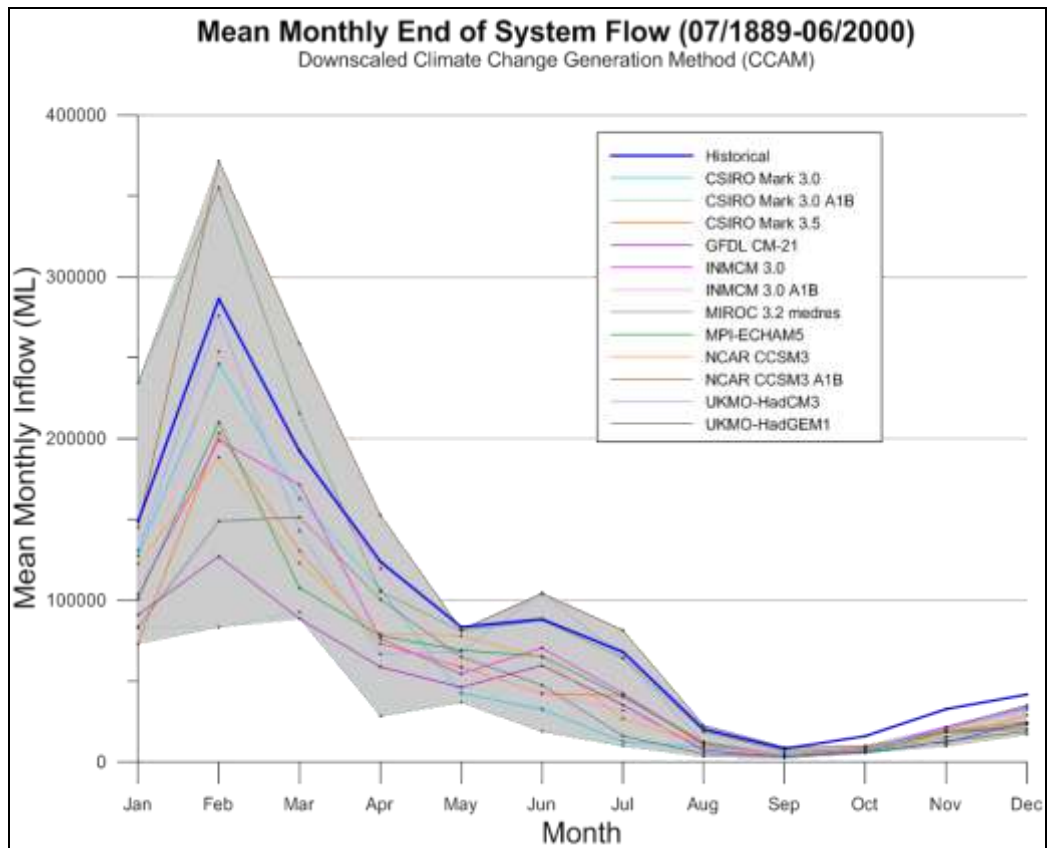


Figure 5.12. Mean Monthly End of System Flow (Node 360) – Historical and Range of CCAM Climate Model Results.

5.2.2. Only Evaporation Climate Change Adjusted

As described in Section 5.2.1, an assessment of the system with only the evaporation adjusted for climate change was also completed for the CCAM models. The Moreton IQQM was re-run for each of the 12 CCAM models assuming no change to rainfall from historical and evaporation change based on the factors described in Section 4.3. As the projected evaporation change is relatively consistent for the various climate models, the range of results is significantly smaller than that described above in Section 5.2.1 (see Figure 5.13 and Figure 5.15). All of the CCAMs show a projected increase in evaporation, and results in the simulated storage volume being less than the historical case.

Figure 5.14 shows the comparisons between the simulated storage volume for the historical and CCAM cases more clearly. In this zoomed plot (1900-1930) it can be observed that the CSIRO Mark 3.5 and GFDL CM21 models have the lowest projected simulated storage volume, while NCAR CCSM3 A1B has the highest projected storage volume. Evaporation is the only feature being adjusted in these cases, and hence the spread of the GCM results is a direct consequence of the evaporation factors described above (Section 4.3). The reduced range of storage volume results is also more clear and noticeable in the zoomed plot (Figure 5.14), particularly compared to the zoomed plot of the storage volume results when both rainfall and evaporation were adjusted for climate change (Figure 5.10).

On the 01/01/1910 the historical simulated storage volume is 1,159,700ML (~75% of FSV), compared to the minimum projected storage volume of 547,940ML (~35% of FSV) (CSIRO Mark 3.5) and the maximum projected volume of 850,330ML (~55% of FSV) (NCAR CCSM3 A1B). These simulated storage volume values are smaller than the GCM results described above (Section 5.1.2). A comparison between the two methods will be further discussed in the following section. See Appendix G – Section G.2 for all CCAM storage plots and Appendix H – Section H.2 for CCAM end of system flow plots.

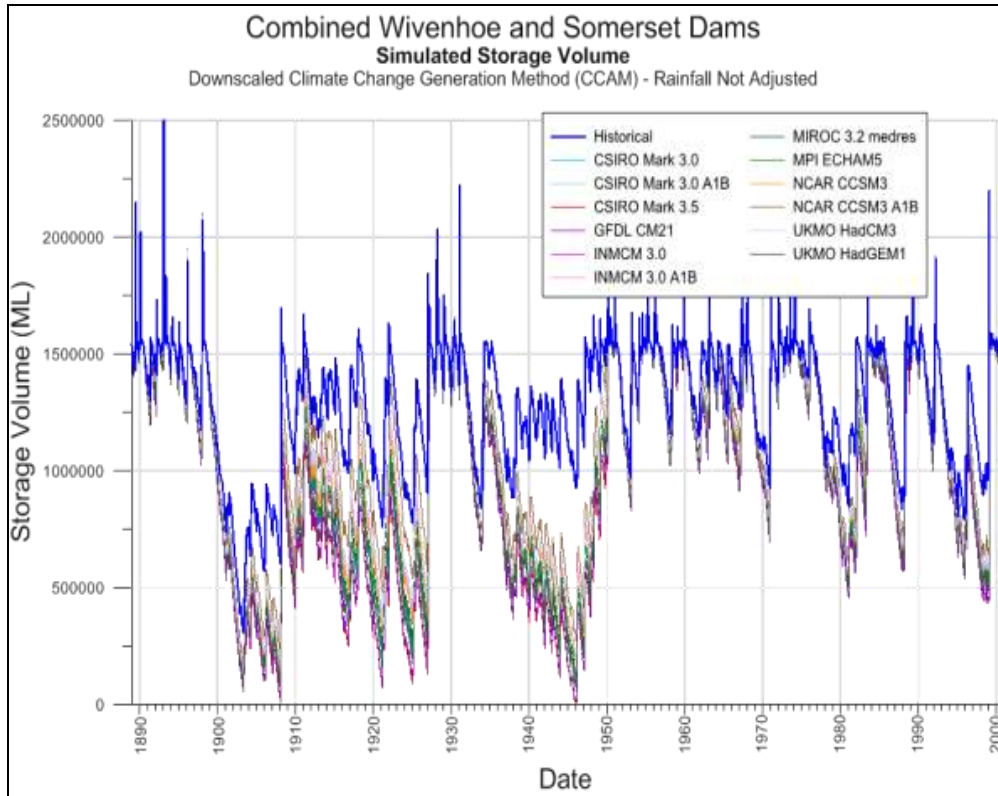


Figure 5.13. Combined Wivenhoe and Somerset Dam Simulated Storage Volume – Historical and CCAM Climate Models (Rainfall Not Adjusted).

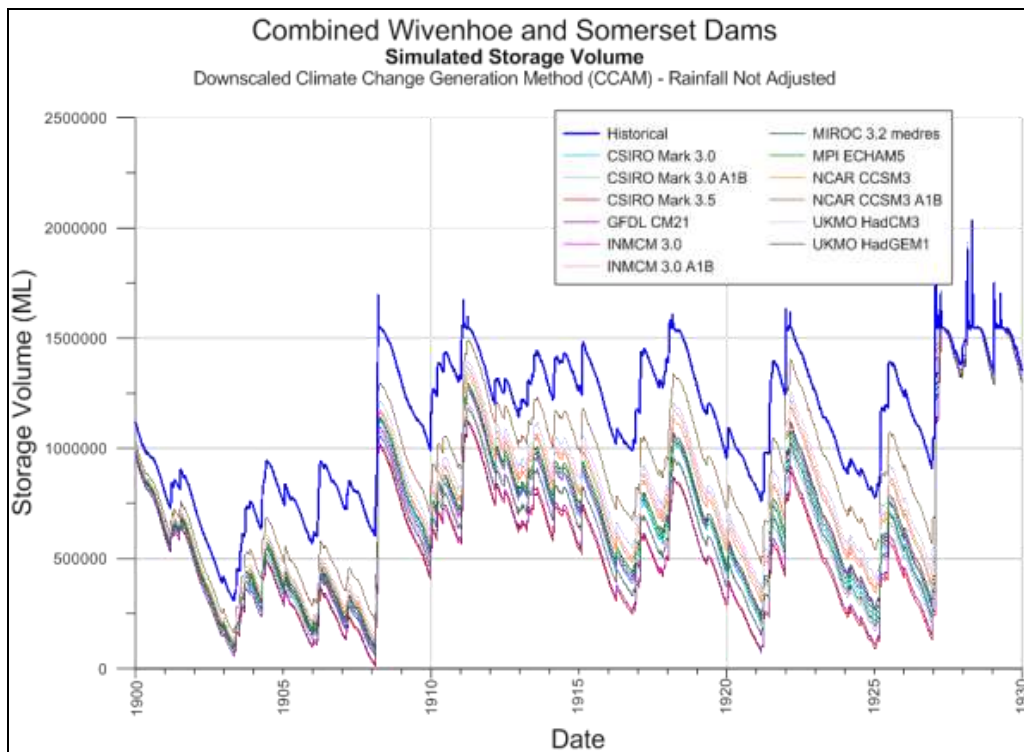


Figure 5.14. Combined Wivenhoe and Somerset Dam Simulated Storage Volume 1900-1930 – Historical and CCAM Climate Models (Rainfall Not Adjusted).

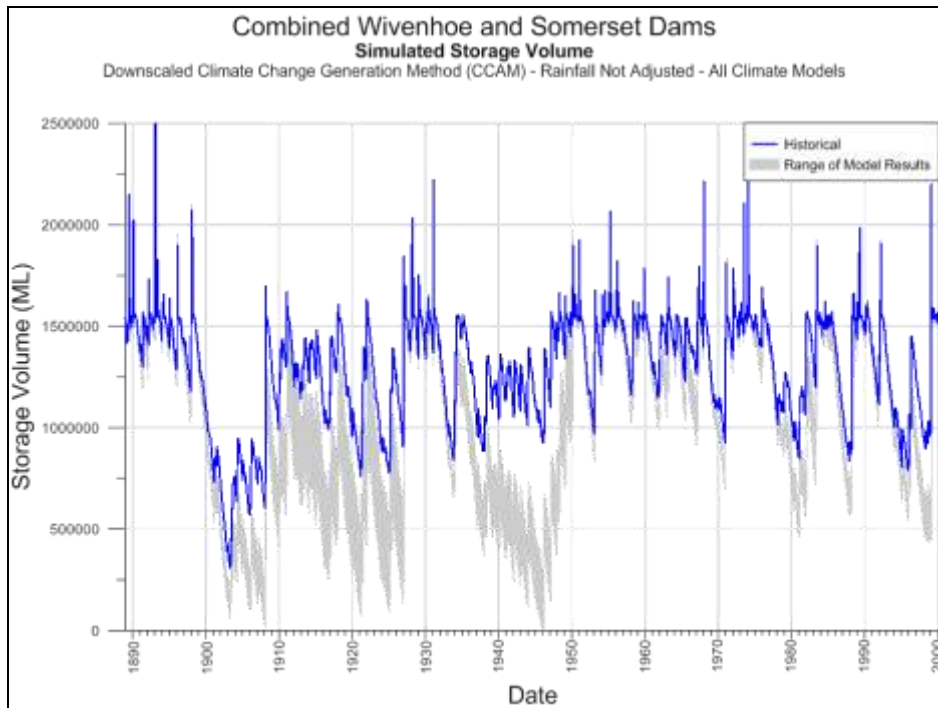


Figure 5.15. Combined Wivenhoe and Somerset Dam Storage Volume – Historical and Range of CCAM Climate Model Results (Rainfall Not Adjusted).

As expected for these runs, the mean monthly end of system flow for the Moreton model shows similar results as those described for the storage behaviour (see Figure 5.16). The range of model results in terms of end of system flow is very small and each of the cases projects a mean monthly flow of less than the historical case. NCAR CCSM3 A1B generally has the largest mean monthly flow at the end of the system, with CSIRO Mark 3.5 and GFDL CM21 having the lowest. In March for example, the mean monthly end of system flow projected by NCAR CCSM3 A1B is 153,377ML which is ~80% of the historical mean monthly end of system flow for the same month. CSIRO Mark 3.5 on the other hand, projects an end of system flow of 134,089ML which is ~70% of the historical equivalent.

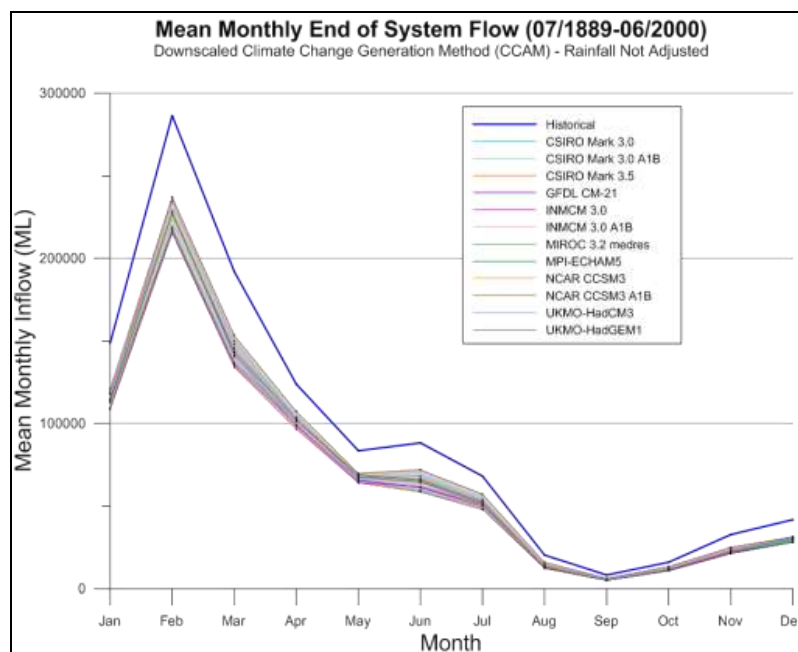


Figure 5.16. Mean Monthly End of System Flow (Node 360) – Historical and Range of CCAM Climate Model Results (Rainfall Not Adjusted).

5.3. Comparison of GCM and CCAM Results

As described and shown in Table 4.2 above, there are eight climate models which are common to the GCM and downscaled GCM (CCAM) generation methods (Table 5.3). Despite this, the Moreton IQQM output presented in sections 5.1 and 1.1 above describe the results of all 11 GCM and 12 CCAM models respectively (see Table 5.1 and Table 5.2). For the following comparisons, the focus is on only the eight common climate models between the two generation methods.

Table 5.3. List of Directly Comparable Climate Models (GCM and CCAM).

Common Climate Models (GCM and CCAM)	GCM Evaporation
CSIRO Mark 3.0 A2	Evaporation
CSIRO Mark 3.5 A2	Evaporation
GFDL CM21 A2	Temperature Relationship
MIROC 3.2 medres A2	Evaporation
MPI ECHAM5 A2	Temperature Relationship
NCAR CCSM3 A2	Evaporation
UKMO HadCM3 A2	Temperature Relationship
UKMO HadGEM1 A2	Temperature Relationship

5.3.1. Rainfall and Evaporation Climate Change Adjusted

As mentioned above, when rainfall and evaporation are both adjusted for climate change there is a significant range of IQQM results. The range of simulated storage volume results for the eight common climate models are given in Figure 5.17 (GCM) and Figure 5.18 (CCAM). As well as the range of model results, these plots include the 80% confidence limits and median model result. As can be seen in Figure 5.17, even with only eight GCM climate models the range of simulated storage results spans from a higher storage volume than the historical sequence to a much lower storage volume in comparison to the historical. The median GCM simulated storage result is also much drier than the simulated historical sequence. For example, on the 01/01/1910 the historical simulated storage volume is 1,159,700ML (~75% of FSV) while the median GCM model result shows a simulated storage volume of 678,285ML (~44% of FSV).

The eight CCAM model results (see Figure 5.18) have a slightly tighter range than that observed for the GCM results. All eight simulated storage results for the CCAM runs are lower than the historical simulated storage for nearly the whole period. The upper bound of the 80% confidence limits for the CCAM storage volume results is lower than the historical sequence and that observed for the GCM results. The median CCAM simulated storage result is also much drier than the historical sequence; the simulated storage volume on 01/01/1910 for the median CCAM result is 516,070ML (~33% of FSV). This result is also drier than the equivalent GCM median result. This comparison between median results for the two generation methods can be better observed in Figure 5.19. As the plot shows, the median CCAM result has a lower simulated storage volume compared to the median GCM result for the whole simulation period. This demonstrates that, on average, climate change downscaling (CCAM) produces drier results than the original GCM climate modelling. This has implications for the way in which climate change data is generated and also for future water planning and policy.

See Appendix G – Section G.3 for all comparison storage plots.

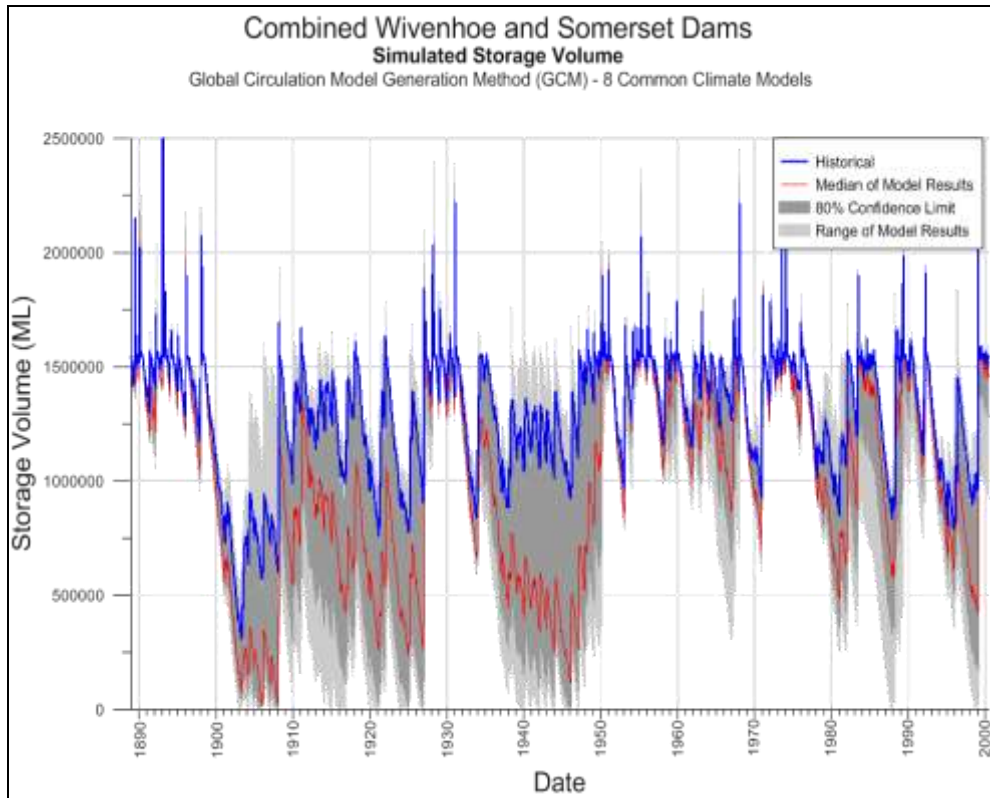


Figure 5.17. Combined Wivenhoe and Somerset Dam Simulated Storage Volume – Historical and Range of GCM Climate Model Results (for 8 Common Climate Models).

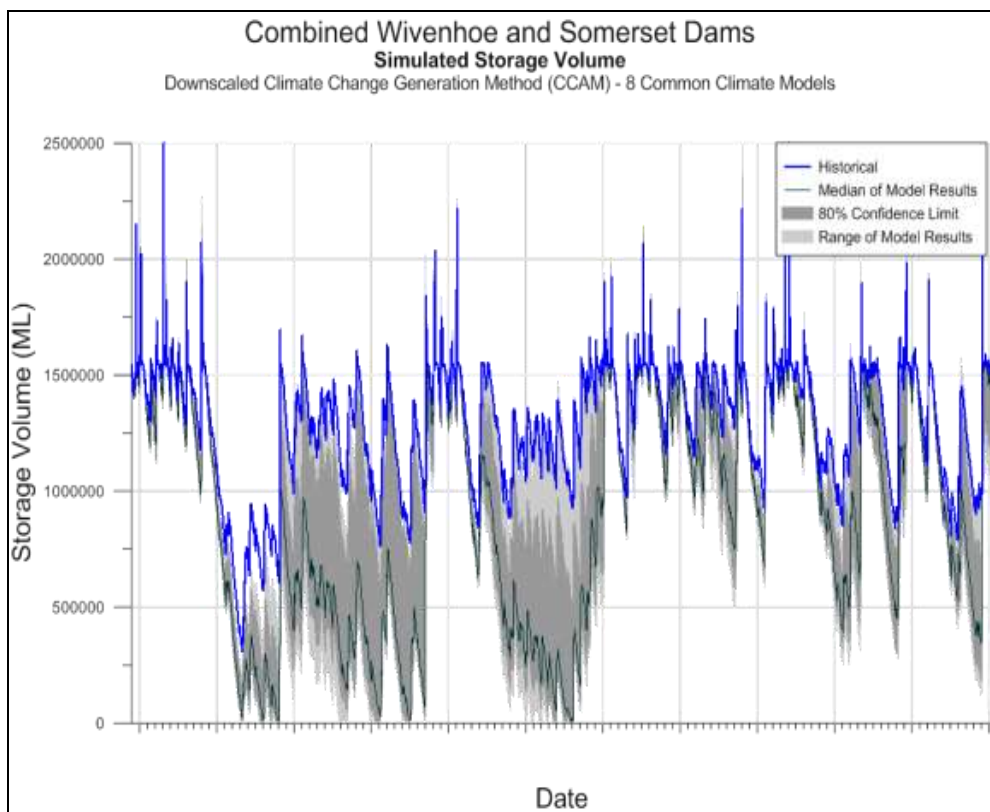


Figure 5.18. Combined Wivenhoe and Somerset Dam Simulated Storage Volume – Historical and Range of CCAM Climate Model Results (for 8 Common Climate Models).

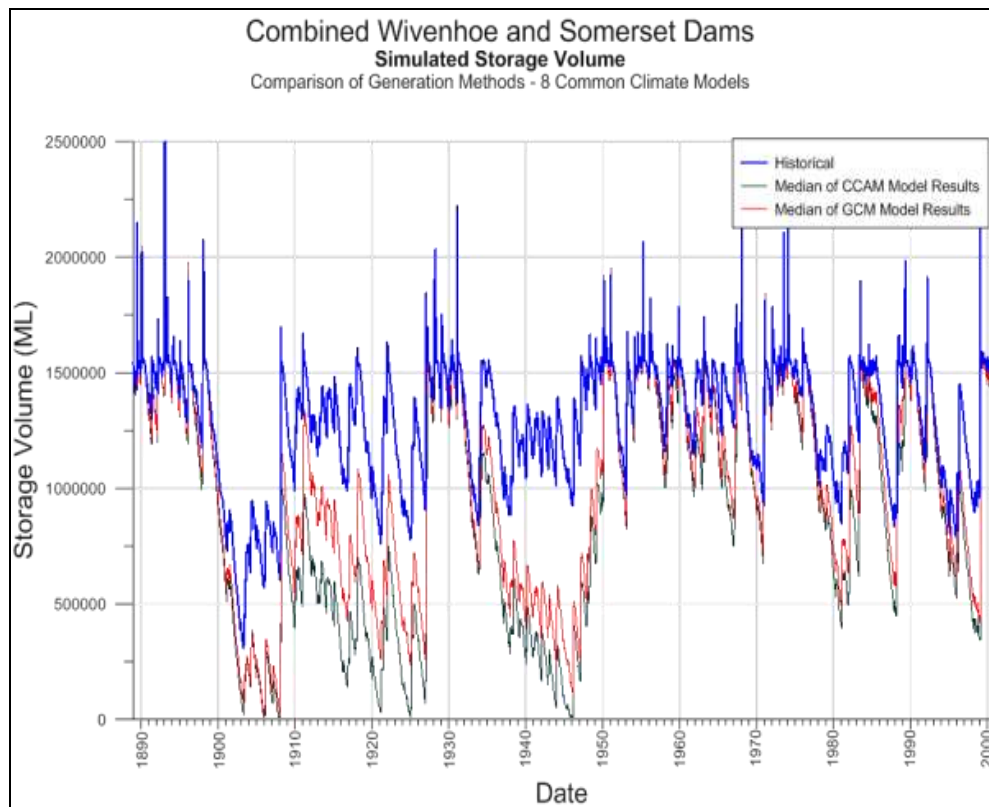


Figure 5.19. Combined Wivenhoe and Somerset Dam Simulated Storage Volume – Historical and Median GCM and CCAM Climate Model Results (for 8 Common Climate Models).

5.3.2. Only Evaporation Climate Change Adjusted

This section shows the comparison of the IQQM results from the eight common models with only evaporation adjusted for climate change. The range of simulated storage volume results for the eight common climate models are given in Figure 5.20 (GCM) and Figure 5.21 (CCAM). As can be observed from these plots, the range of model results for both the GCM and CCAM generation methods is significantly less than that shown in Section 5.3.1. This is consistent with the fact that the evaporation factors are more consistent (than the rainfall factors) across the various climate models for both the GCM and downscaled factor sets. As well as the range of model results, these plots include the 80% confidence limits and median model result. As can be seen in Figure 5.20, the range of simulated storage results for the eight GCM models is much smaller than that shown in Figure 5.17. The median GCM simulated storage result is still drier than the simulated historical sequence, but not as dry as the median result when both rainfall and evaporation are adjusted. On the 01/01/1910 the median GCM model result for the evaporation only cases shows a simulated storage volume of 903,130ML (~58% of FSV).

The eight CCAM model results (see Figure 5.21) have a slightly tighter range than that observed for the GCM results. The range of CCAM results is drier than that observed for the GCM results. The median CCAM simulated storage result is still drier than the historical sequence and the equivalent GCM result, but not as dry as the median result when both rainfall and evaporation are adjusted. The simulated storage volume on 01/01/1910 for the median CCAM result is 666,060ML (~43% of FSV). This comparison between median results for the two generation methods can be better observed in Figure 5.22. As the plot shows, the median CCAM result has a lower simulated storage volume compared to the median GCM result for the whole simulation period. This demonstrates that, on average, even with only evaporation adjusted, climate change downscaling (CCAM) produces drier results than the original GCM climate modelling. See Appendix G – Section G.3 for all comparison storage plots.

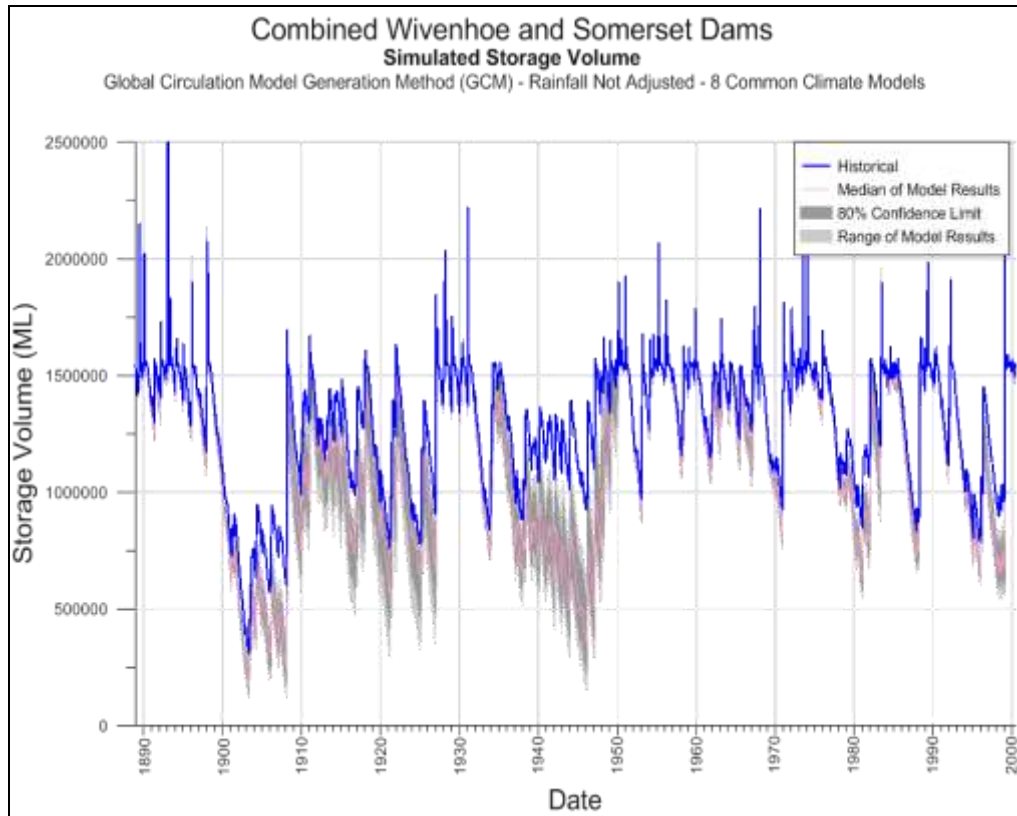


Figure 5.20. Combined Wivenhoe and Somerset Dam Simulated Storage Volume – Historical and Range of GCM Climate Model Results (Rainfall Not Adjusted) (for 8 Common Climate Models).

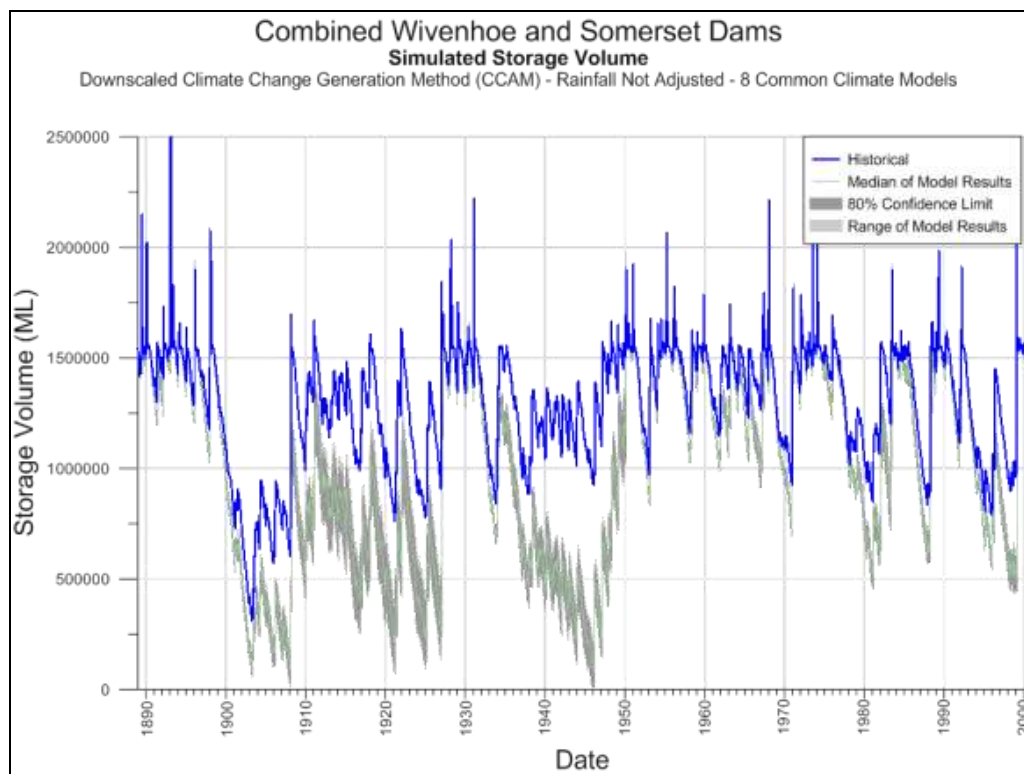


Figure 5.21. Combined Wivenhoe and Somerset Dam Simulated Storage Volume – Historical and Range of CCAM Climate Model Results (Rainfall Not Adjusted) (for 8 Common Climate Models).

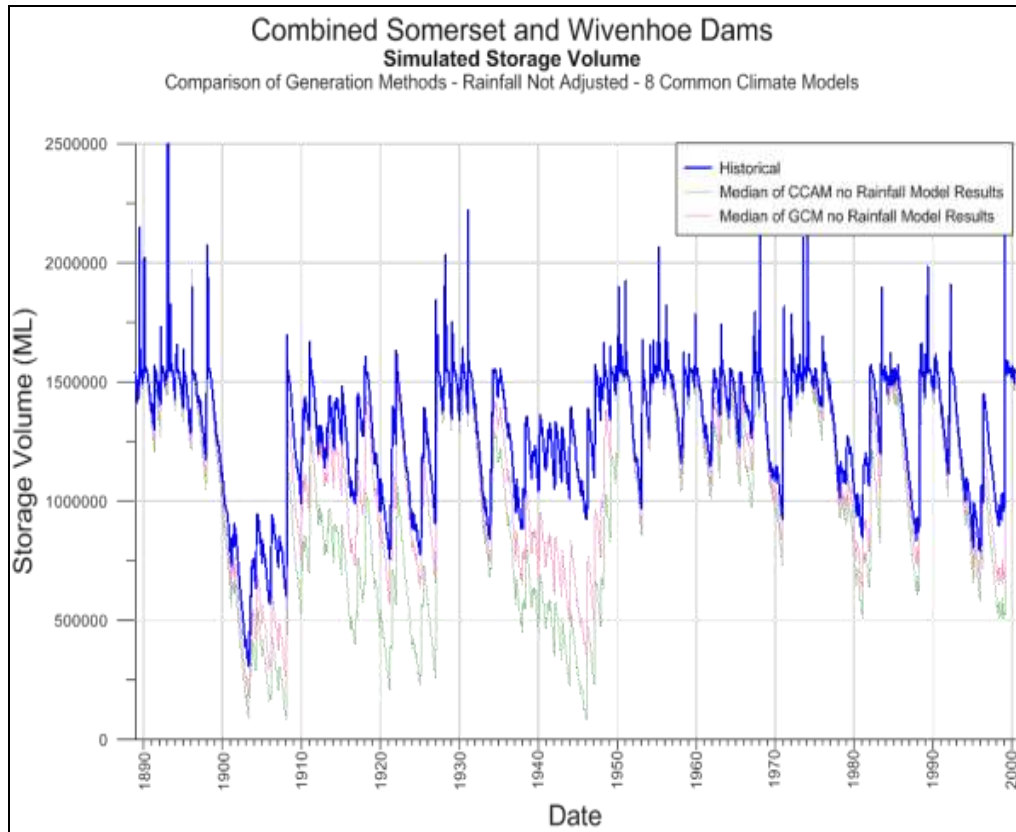


Figure 5.22. Combined Wivenhoe and Somerset Dam Simulated Storage Volume – Historical and Median GCM and CCAM Climate Model Results (Rainfall Not Adjusted) (for 8 Common Climate Models).

5.3.3. Comparison of GFDL CM21 Results

As a further comparison of the climate change generation methods, a comparison of results obtained for the GFDL CM21 climate model are presented in this section. GFDL CM21 data was generated for the GCM, CCAM, CCAM PPE1 and CCAM PPE2 generation methods (see Table 4.2). GFDL CM21 is one of the drier climate models, owing to a high projected increase in evaporation and a significant projected decrease in rainfall across most months. It should be noted that evaporation figures for the GCM projections for GFDL CM21 are produced using the relationship between evaporation and temperature from the six GCMs that output evaporation. So, comparisons between the GCM and CCAM projections for evaporation change for this model are indicative only.

Figure 5.23 shows a comparison of simulated storage volume (of combined Wivenhoe and Somerset Dams) under GFDL CM21 for the GCM and CCAM generation methods. For the two generation methods, the simulated storage behaviour is displayed for the case where rainfall and evaporation are adjusted, as well as the case where only evaporation is adjusted. Where rainfall and evaporation are both adjusted, the simulated storage behaviour is very low compared to the historical case. For these two cases, the GCM storage level is lower than the CCAM level for the majority of the simulation period. When only evaporation was adjusted for the GFDL CM21 cases, the CCAM simulated storage result was lower than that of GCM method (see Figure 5.23). This shows that the projected evaporation change is higher for the CCAM method than the GCM method under GFDL CM21 (this is consistent with the evaporation information presented in Section 4.3.3.3 and Figure 4.17 above). As can be observed from Figure 5.23, there is a range of possible results depending on the generation method chosen.

Plots of the comparisons between the simulated storage volume for the GCM and CCAM generation methods under the eight common climate models can be found in Appendix G – Section G.3.1.

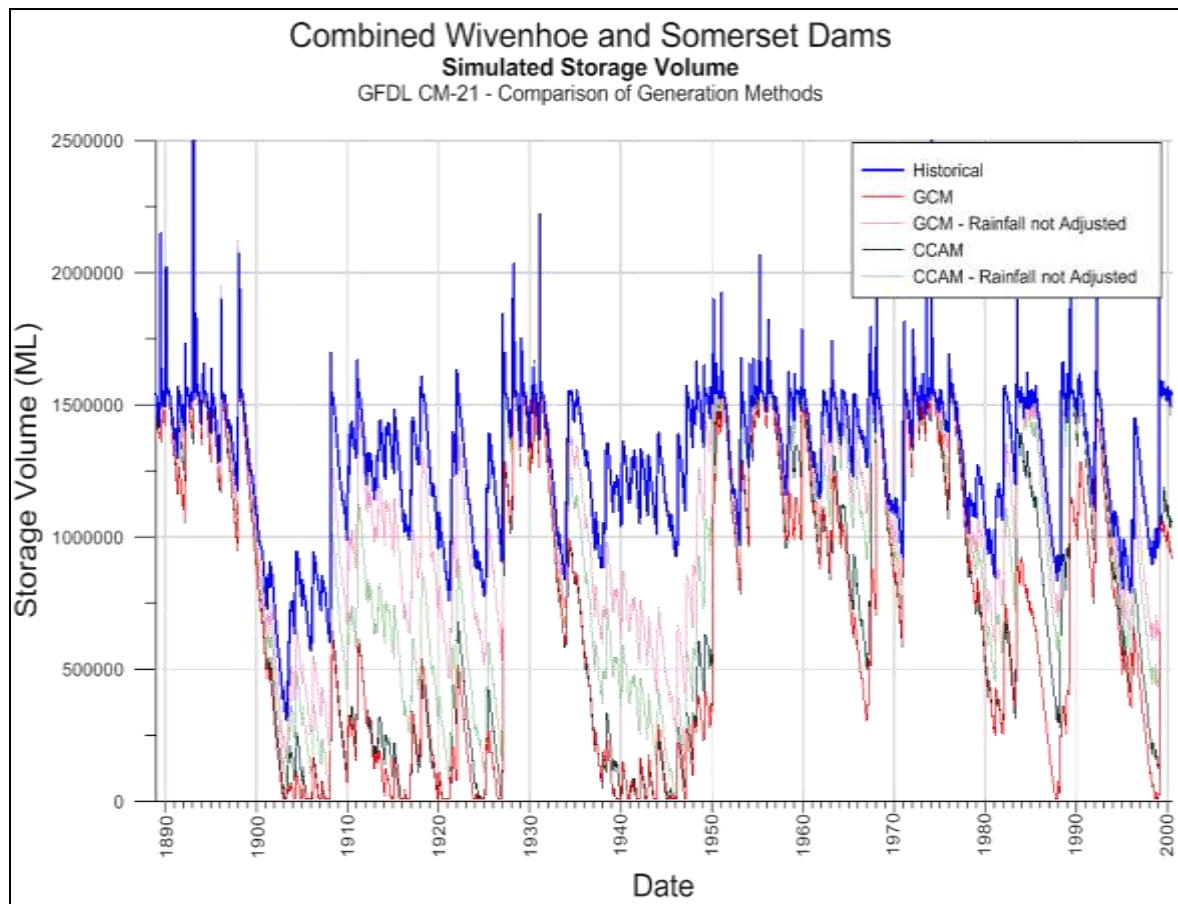


Figure 5.23. Combined Wivenhoe and Somerset Dam Simulated Storage Volume – Historical, GCM and CCAM – GFDL CM21 (With and Without Rainfall Adjusted).

A comparison of the combined simulated storage volume for Wivenhoe and Somerset Dams for the GCM, CCAM and CCAM PPE1 generation methods can be found in Figure 5.24. The simulated storage volume results for all of the cases show again that GFDL CM21 is a dry climate model. Of note in this plot, the CCAM PPE1 8km generation method gives the worst results in terms of storage performance. This is a reflection of the significant evaporation increase and rainfall decrease projected by CCAM PPE1 when downscaled to 8km. This plot again shows the range in results that are obtained from different downscaling resolutions of a single climate model.

Plots of the comparisons between the simulated storage volume for the GCM, CCAM and CCAM PPE1 generation methods under GFDL CM21 can be found in Appendix G – Section G.3.2.

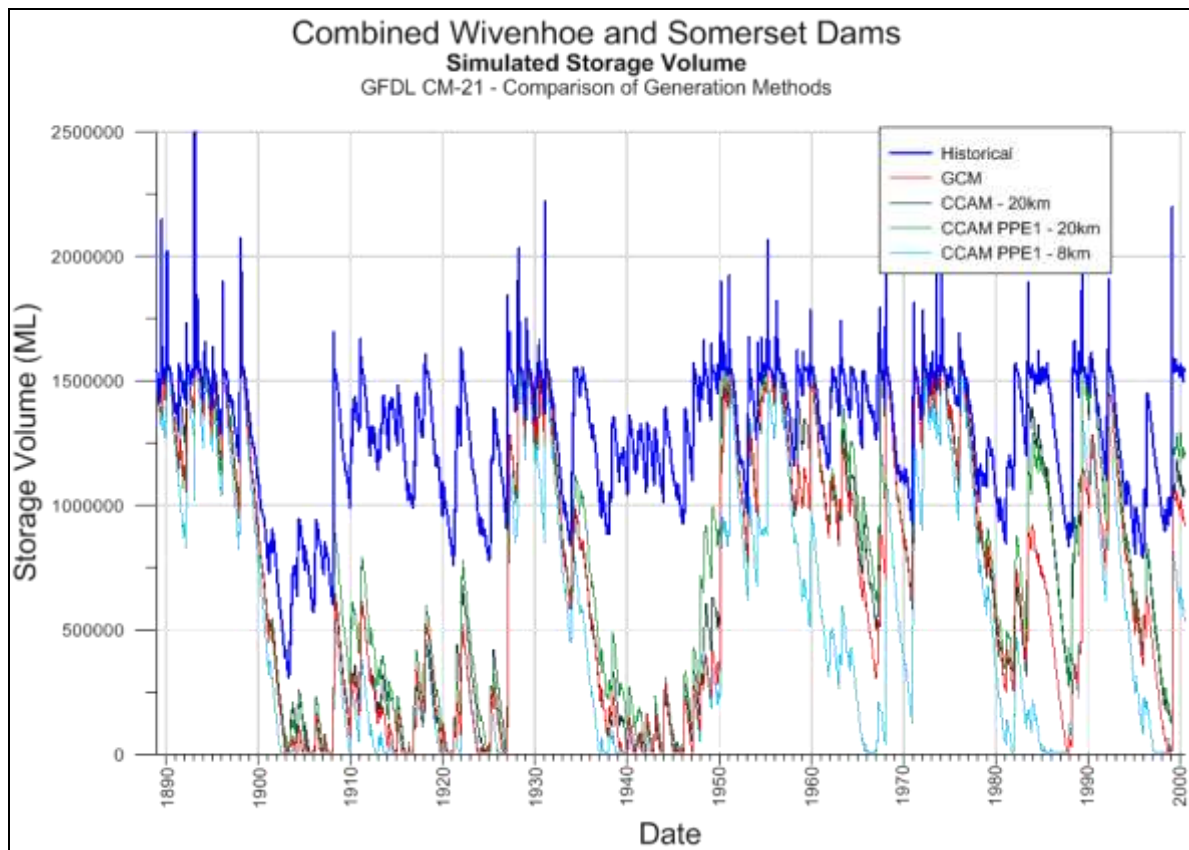


Figure 5.24. Combined Wivenhoe and Somerset Dam Simulated Storage Volume – Historical, GCM, CCAM and CCAM PPE1 – GFDL CM21.

The end of system flow results under GFDL CM21 shows a similar pattern to that described for the simulated storage volume results. Figure 5.25 shows the end of system flow for the GCM and CCAM generation methods – both with rainfall and evaporation adjusted, and only evaporation adjusted. For the cases where both rainfall and evaporation are adjusted, the mean monthly end of system flow for GCM is greater than for CCAM in the summer months. For the other months, the CCAM end of system flow is greater. For the cases with only evaporation adjusted, the mean monthly GCM end of system flow is greater for each month. Plots of the comparisons between the end of system flow for the GCM and CCAM generation methods under the remaining of the eight common climate models can be found in Appendix H – Section H.3.1.

Figure 5.26 shows the comparison of end of system flow under GFDL CM21 for GCM, CCAM and CCAM PPE1. As with the simulated storage volume, the CCAM PPE1 8km case has the lowest mean monthly inflow overall. Plots of the comparisons between the end of system flow for the GCM, CCAM and CCAM PPE1 generation methods under GFDL CM21 can be found in Appendix H – Section H.3.2.

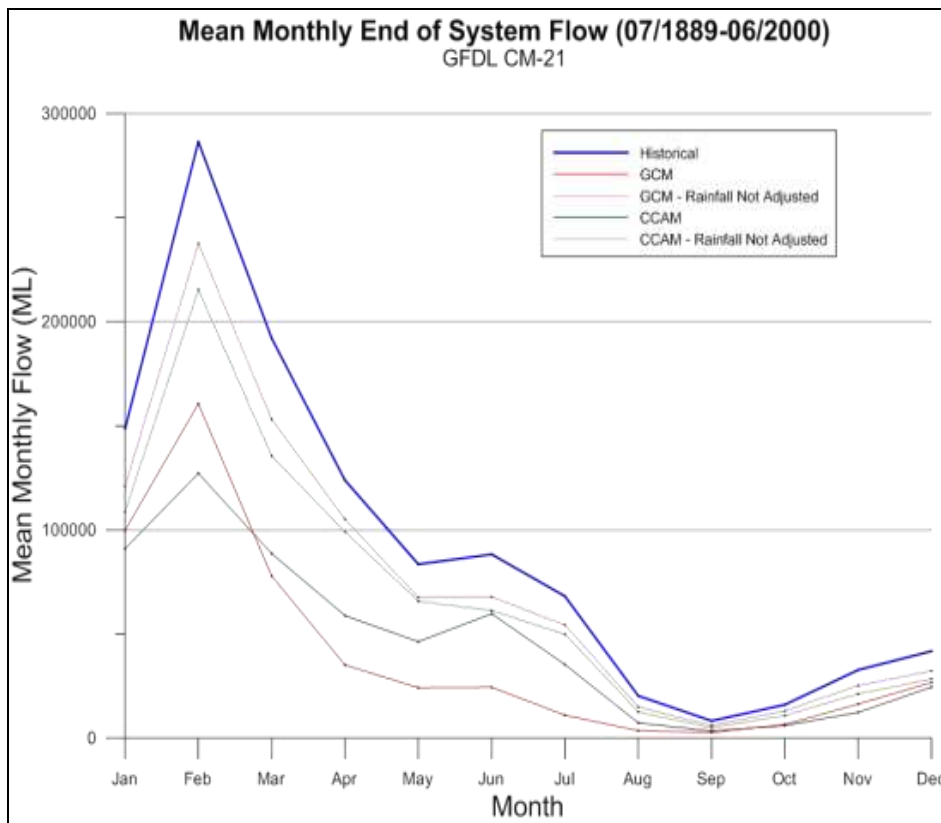


Figure 5.25. Mean Monthly End of System Flow (Node 360) – Historical, GCM and CCAM – GFDL CM21 (With and Without Rainfall Adjusted).

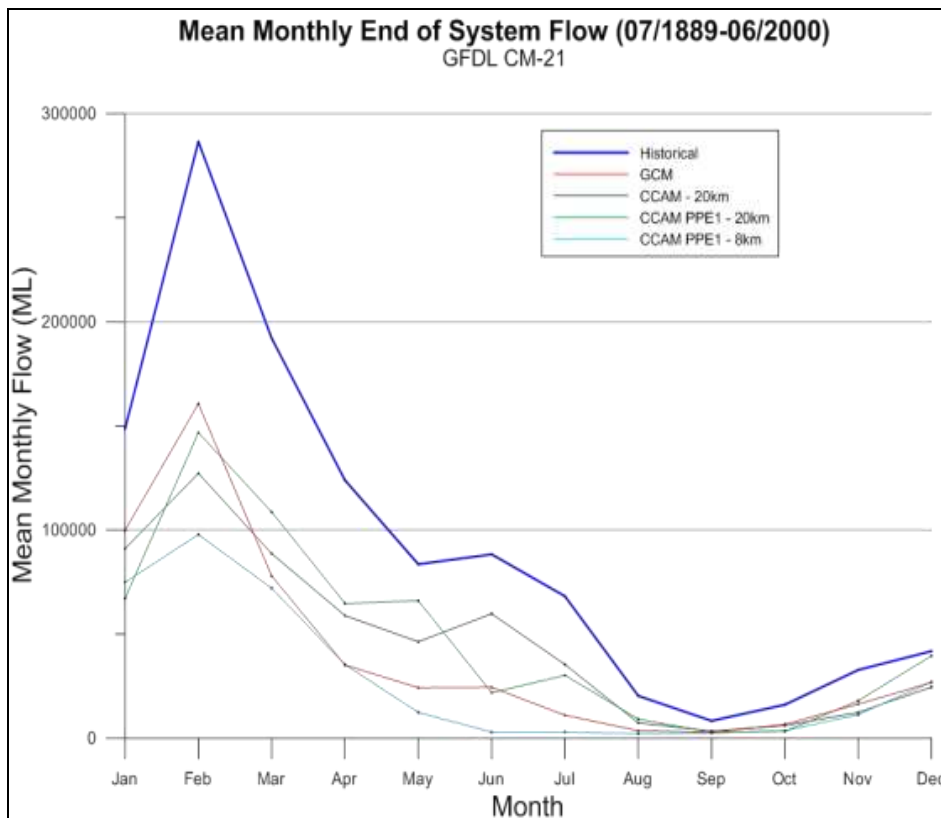


Figure 5.26. Mean Monthly End of System Flow (Node 360) – Historical, GCM, CCAM and CCAM PPE1 – GFDL CM21.

6. IMPLICATIONS FOR WATER AVAILABILITY IN SEQ

For this study, water availability has been assessed using a similar method to the Level of Service (LoS) approach developed for the Regional Water Supply Strategy process in Queensland. The performance of the combined Wivenhoe and Somerset Dams is assessed using the frequency of years where the available storage volume falls below specific trigger levels, expressed as an average recurrence interval. The trigger levels for this analysis have been arbitrarily chosen as 75%, 50% and 25% of the total full supply volume of both storages, and the combined dead storage volume.

6.1. Analysis of Downscaled Rainfall and Evaporation Projections

The LoS analysis (Table 6.1) shows that, for the majority of models, downscaling is resulting in an increase in the frequency of years where the available storage volume is below the specified trigger levels. Six of the eight directly comparable models show that downscaling results in a decrease in the recurrence interval at the 25%, 50% and 75% trigger levels. The additional downscaled GCMs are also showing significantly decreased recurrence intervals when compared to the additional GCM results.

The average recurrence interval of the combined volume of Wivenhoe and Somerset Dams falling below the specified trigger levels is shown for the GCM and downscaled climate model runs in Figure 6.1 and Figure 6.3, respectively. For both of the generation methods, the GFDL CM21 and UKMO HadGEM1 global climate models fall below the specified trigger levels more frequently in comparison to other common models. In the range of downscaled models, CSIRO Mark 3.0 A1B also experiences frequent events below the specified trigger levels.

Table 6.1. Average Recurrence Interval of Years Where Combined Storage (Wivenhoe and Somerset Dams) Falls below Specified Trigger Levels – Historical, GCM and CCAM.

Climate Model	CCAM				GCM			
	Dead Storage Volume	25%	50%	75%	Dead Storage Volume	25%	50%	75%
	8,886ML	386,000ML	773,000ML	1,159,000ML	8,886ML	386,000ML	773,000ML	1,159,000ML
Historical	>111.0	111.0	12.3	2.1	>111.0	111.0	12.3	2.1
CSIRO Mark 3.0 A2	37.0	3.8	2.1	1.4	>111.0	13.9	3.2	1.5
CSIRO Mark 3.5 A2	15.9	3.0	2.0	1.4	>111.0	6.9	2.3	1.4
GFDL CM21 A2	6.2	2.5	1.8	1.3	4.6	2.1	1.6	1.3
MIROC 3.2 medres A2	>111.0	27.8	6.9	1.7	>111.0	>111.0	37.0	3.6
MPI ECHAM5 A2	13.9	3.0	1.9	1.4	37.0	4.4	2.2	1.4
NCAR CCSM3 A2	55.5	3.8	2.1	1.4	>111.0	27.8	6.9	1.8
UKMO HadCM3 A2	>111.0	12.3	2.8	1.5	55.5	5.8	2.2	1.4
UKMO HadGEM1 A2	12.3	3.1	1.9	1.3	22.2	3.6	2.0	1.4
CSIRO Mark 3.0 A1B	4.1	2.0	1.6	1.2				
INMCM 3.0 A2	>111.0	7.9	2.5	1.4				
INMCM 3.0 A1B	111.0	6.5	2.5	1.4				
NCAR CCSM3 A1B	>111.0	111.0	11.1	2.2				
IAP FGOALS G1.0 A1B					>111.0	13.9	2.8	1.5
MIROC 3.2 hires A1B					>111.0	55.5	13.9	2.4
MIUB ECHO G A2					>111.0	>111.0	18.5	2.8

The impact of downscaling is also easily seen by plotting the modelled storage behaviour of the GCM and downscaled GCM projections (see Section 1.1). Figure 6.2 and Figure 6.4 show the range of the combined Wivenhoe and Somerset Dam storage volumes for the eight common GCM and downscaled GCM model results respectively. These figures include the arbitrary trigger levels tested. While the full range of modelled storage behaviour for both methods is similar, the majority of downscaled models result in more frequent and longer lasting periods of reduced available storage, as shown by the median and 80th percentile confidence limits.

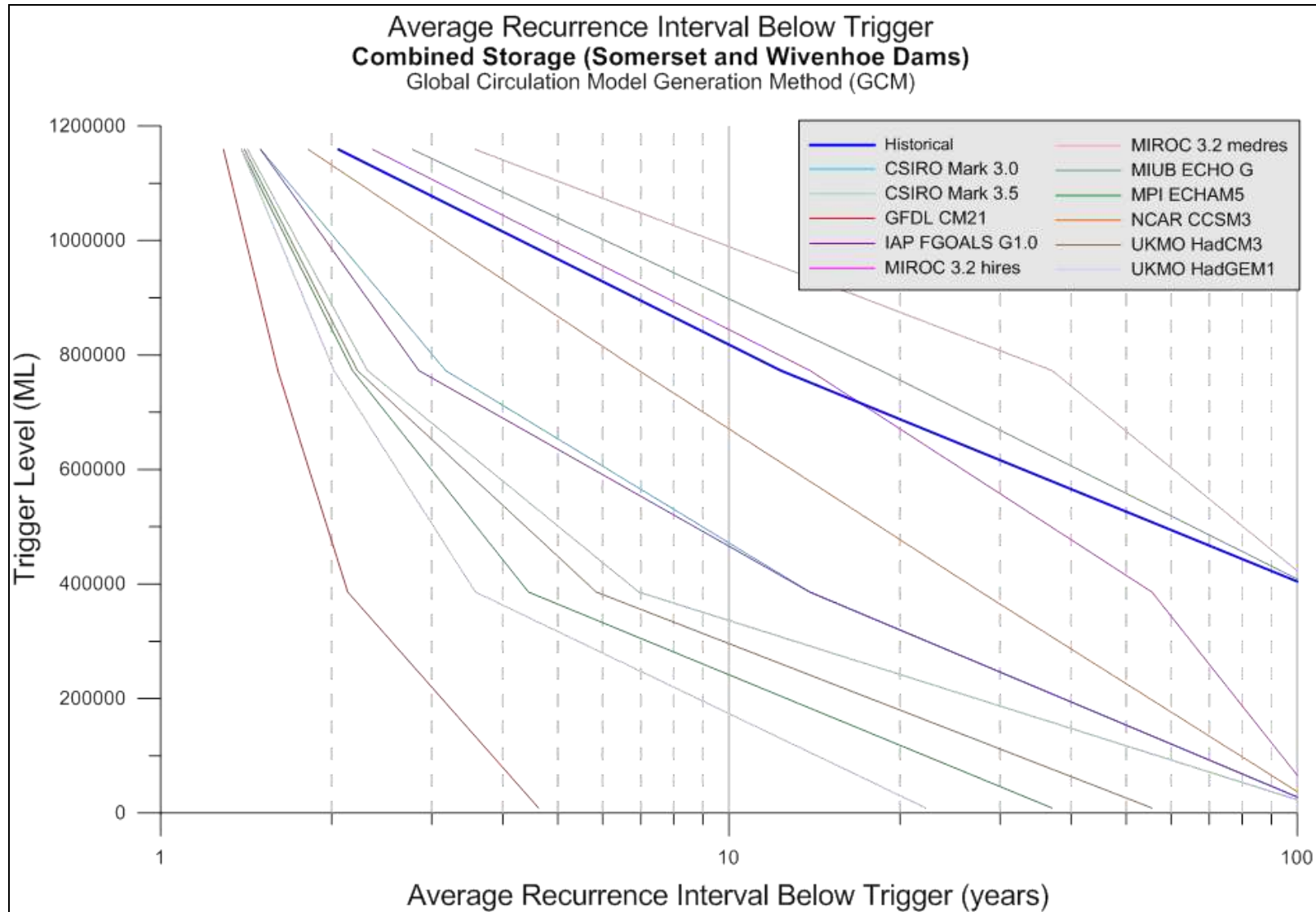


Figure 6.1. Average Recurrence Interval Below Specified Trigger Levels - Combined Wivenhoe and Somerset Dams – Historical and GCM Climate Model Results.

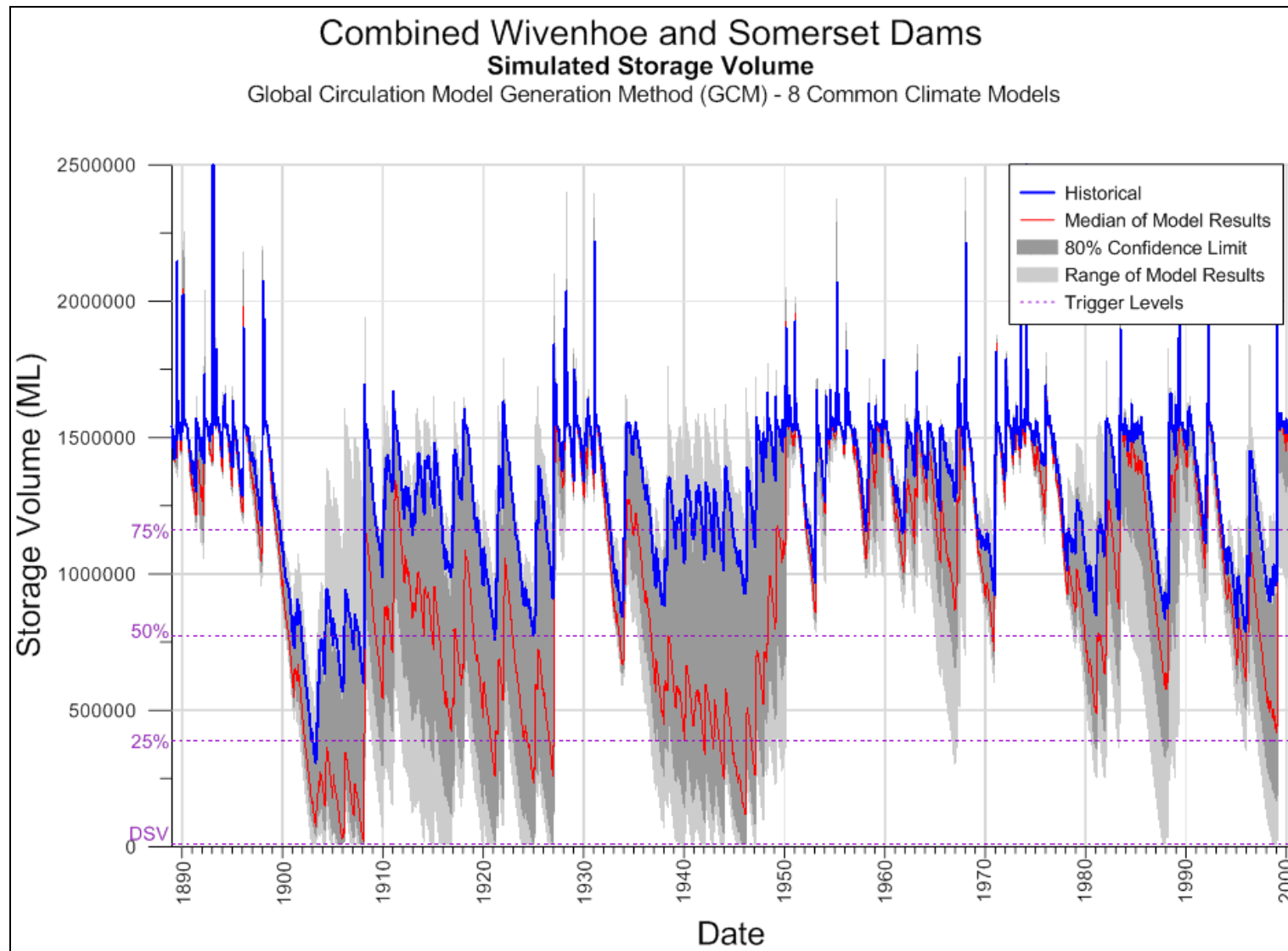


Figure 6.2. Combined Wivenhoe and Somerset Dam Simulated Storage Volume – Historical and Range of GCM Climate Model Results with Specified Trigger Levels (for 8 Common Climate Models).

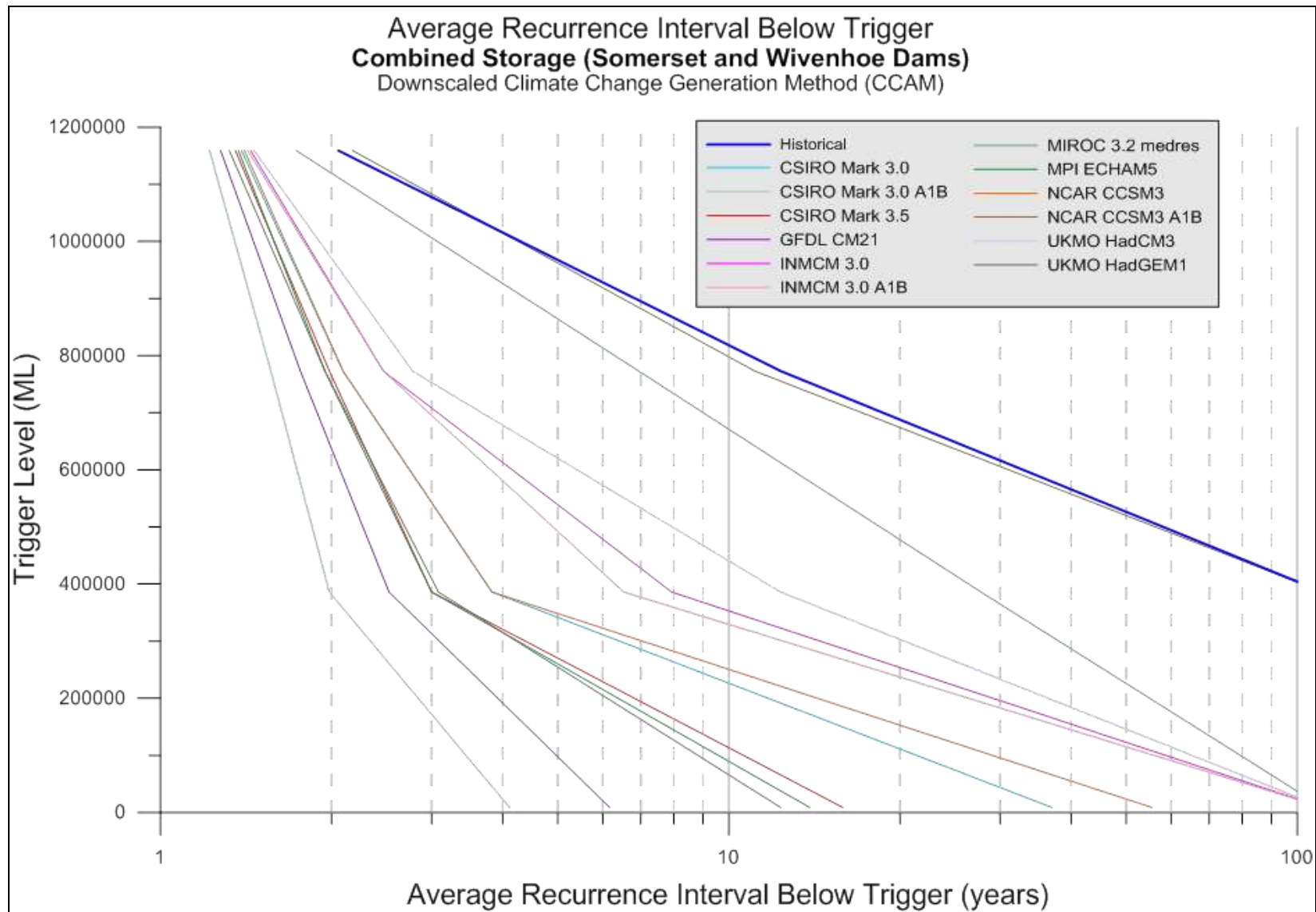


Figure 6.3. Average Recurrence Interval Below Specified Trigger Levels - Combined Wivenhoe and Somerset Dams – Historical and CCAM Climate Model Results.

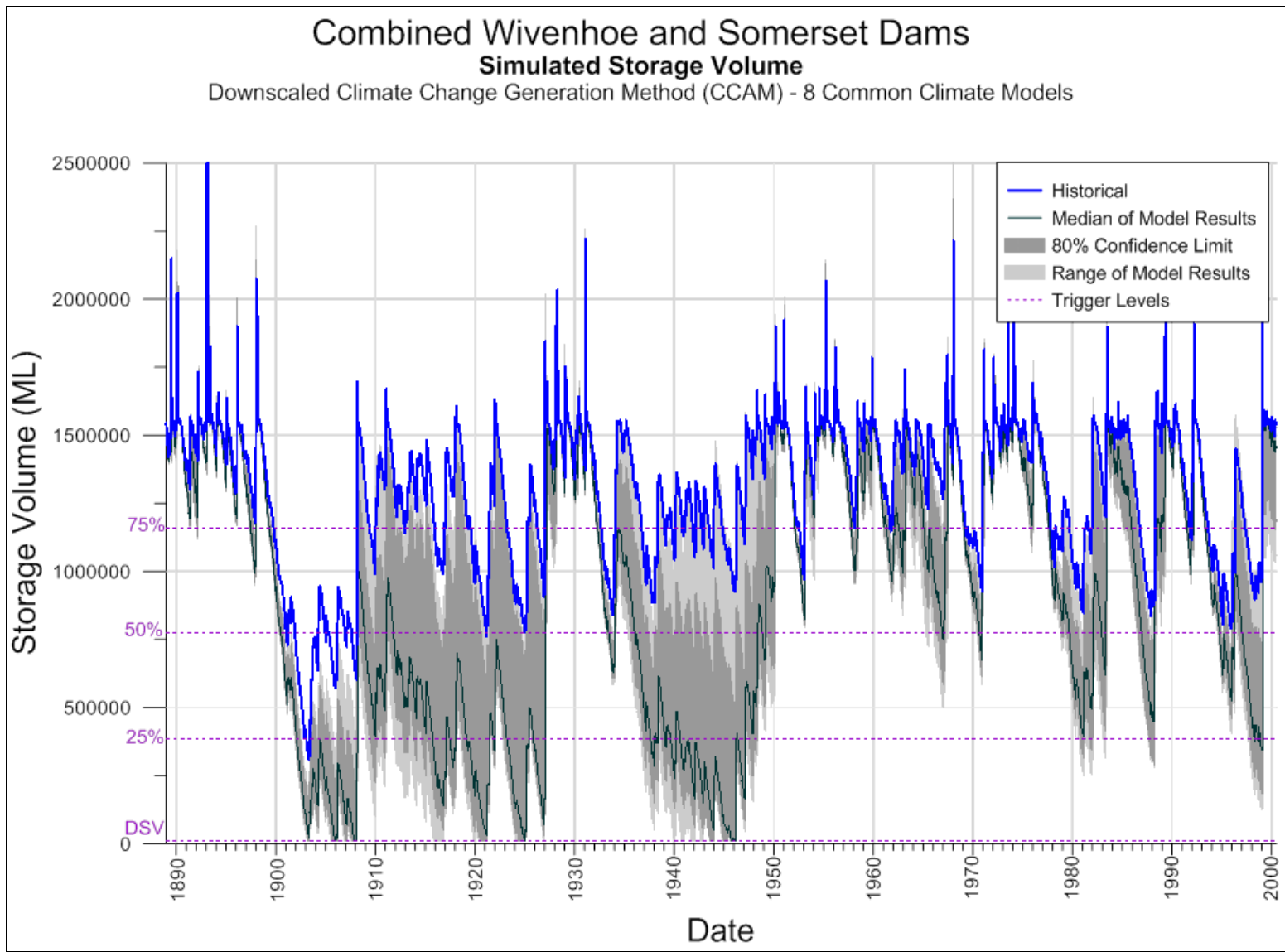


Figure 6.4. Combined Wivenhoe and Somerset Dam Simulated Storage Volume – Historical and Range of CCAM Climate Model Results with Specified Trigger Levels (for 8 Common Climate Models).

6.2. Analysis of downscaled projections with rainfall not adjusted

Removing the uncertainty associated with rainfall projections results in more consistent projected impacts on water availability, across both the GCM and CCAM data sets, shown in Table 6.2. As with the analyses presented in section 6.1, the CCAM results show an increase in the frequency of events where the combined volume of Wivenhoe and Somerset Dams falls below each specified trigger level. This is due to higher rates of evaporation change from the CCAM projections.

When comparing the plots of storage behaviour shown in Figures 6.6 and 6.8, the range of results from the downscaled CCAM projections is significantly less than the GCM projections, which can be attributed to the method of calculation of evaporation change between the two methodologies. This is also evident when comparing the frequency of events below the specified trigger levels, shown in Figures 6.5 and 6.7.

Table 6.2. Average Recurrence Interval of Years Where Combined Storage (Wivenhoe and Somerset Dams) Falls below Specified Trigger Levels – Historical, GCM and CCAM (Rainfall Not Adjusted).

Model	CCAM - Rainfall not Adjusted				GCM - Rainfall Not Adjusted			
	Dead Storage Volume	25%	50%	75%	Dead Storage Volume	25%	50%	75%
	8,886ML	386,000ML	773,000ML	1,159,000ML	8,886ML	386,000ML	773,000ML	1,159,000ML
Historical	>111.0	111.0	12.3	2.1	>111.0	111.0	12.3	2.1
CSIRO Mark 3.0 A2	>111.0	6.2	2.2	1.4	>111.0	7.9	2.4	1.4
CSIRO Mark 3.5 A2	111.0	4.4	2.1	1.4	>111.0	18.5	3.0	1.6
GFDL CM21 A2	111.0	4.4	2.1	1.4	>111.0	15.9	2.9	1.5
MIROC 3.2 medres A2	>111.0	6.9	2.4	1.4	>111.0	37.0	6.5	1.8
MPI ECHAM5 A2	>111.0	6.5	2.3	1.4	>111.0	18.5	3.4	1.6
NCAR CCSM3 A2	>111.0	7.9	2.5	1.5	>111.0	27.8	4.4	1.7
UKMO HadCM3 A2	>111.0	9.3	2.7	1.5	>111.0	18.5	3.5	1.6
UKMO HadGEM1 A2	>111.0	5.8	2.2	1.4	>111.0	27.8	4.3	1.7
CSIRO Mark 3.0 A1B	>111.0	5.6	2.2	1.4				
INMCM 3.0 A2	>111.0	6.5	2.2	1.4				
INMCM 3.0 A1B	>111.0	7.9	2.5	1.5				
NCAR CCSM3 A1B	>111.0	15.9	2.9	1.5				
IAP FGOALS G1.0 A1B					>111.0	27.8	4.4	1.7
MIROC 3.2 hires A1B					>111.0	27.8	4.4	1.7
MIUB ECHO G A2					>111.0	55.5	7.4	1.8

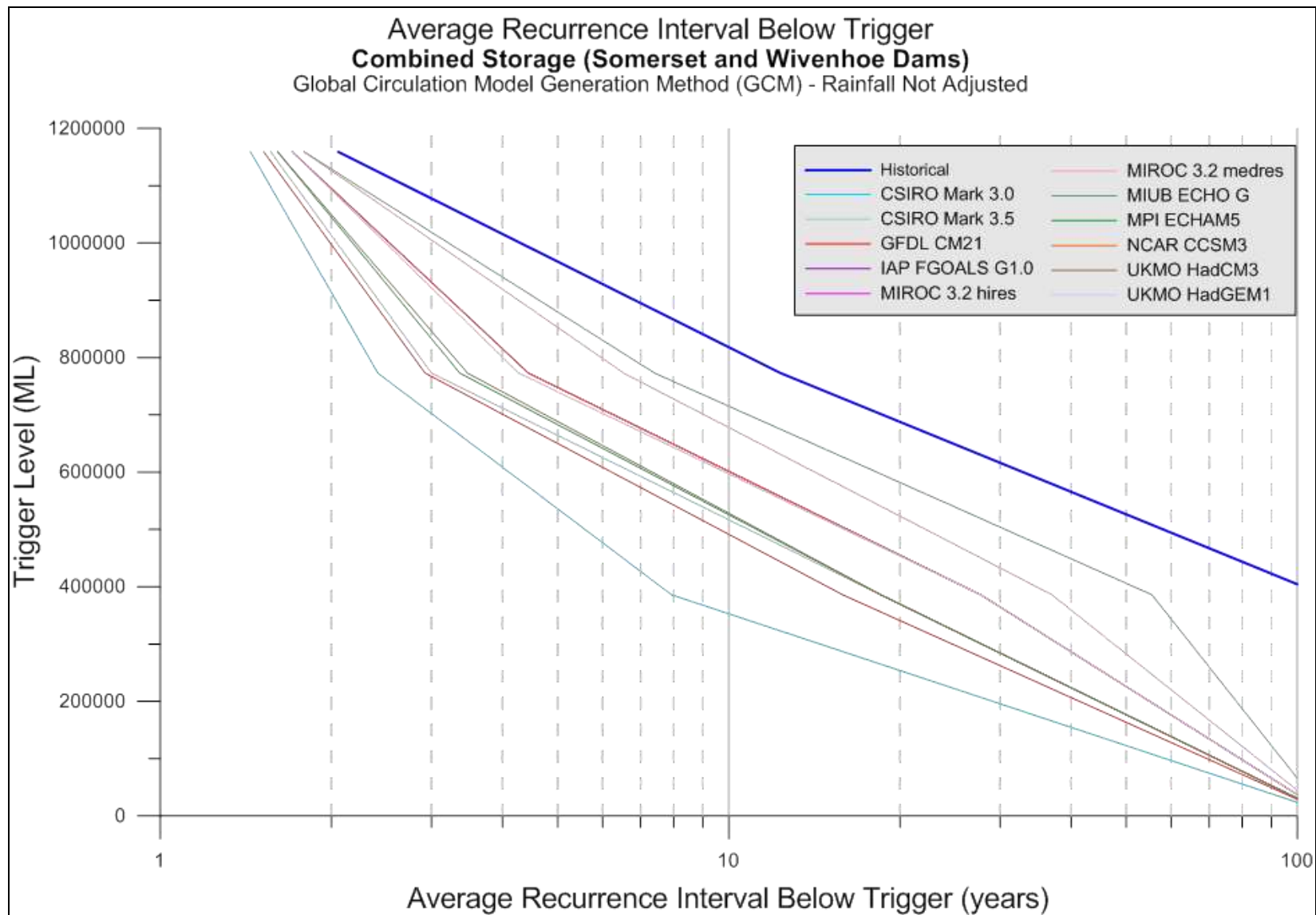


Figure 6.5. Average Recurrence Interval Below Specified Trigger Levels - Combined Wivenhoe and Somerset Dams – Historical and GCM Results (Rainfall Not Adjusted).

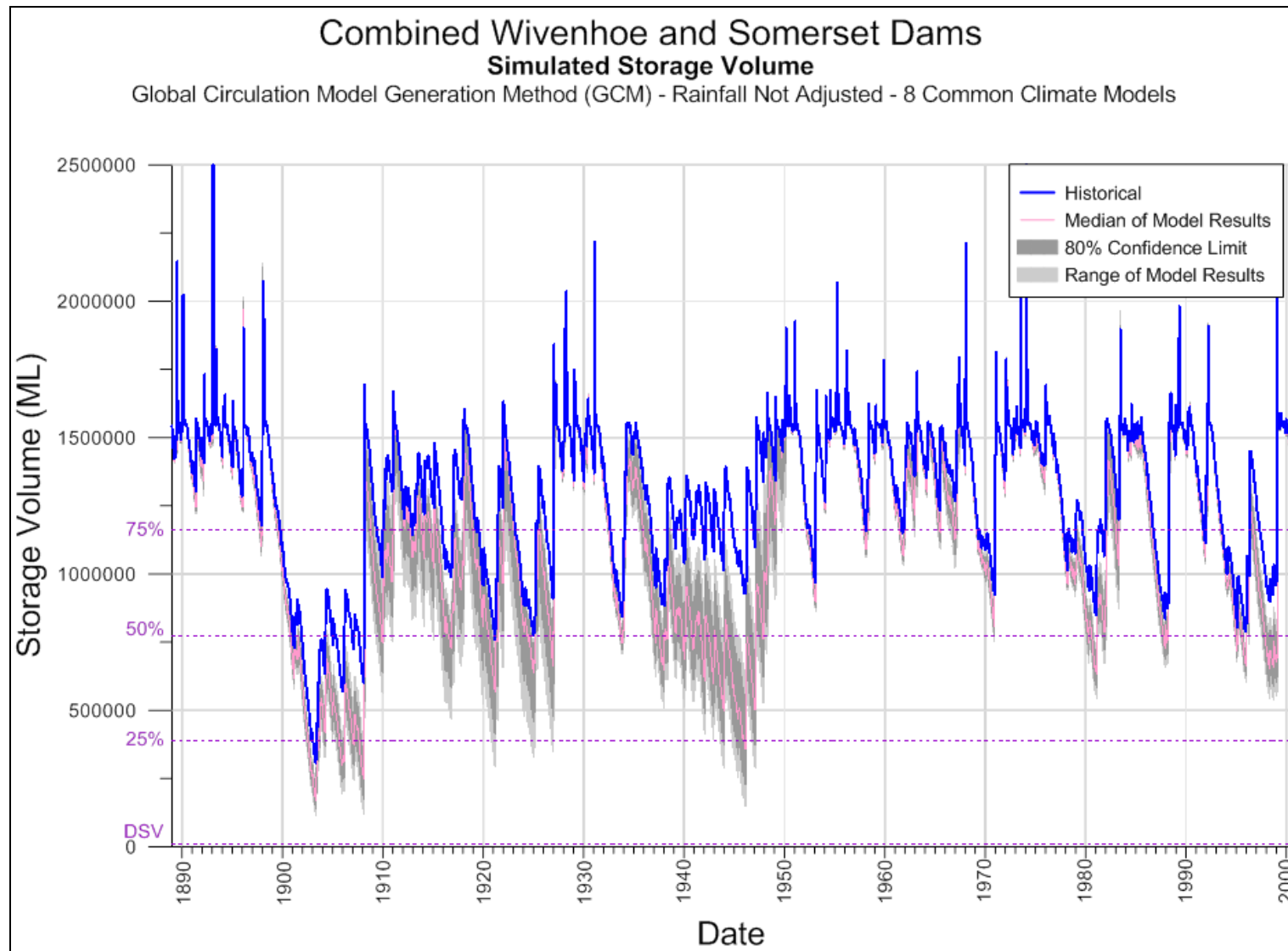


Figure 6.6. Combined Wivenhoe and Somerset Dam Simulated Storage Volume – Historical and Range of GCM Results with Specified Trigger Levels (for 8 common GCM) (Rainfall Not Adjusted).

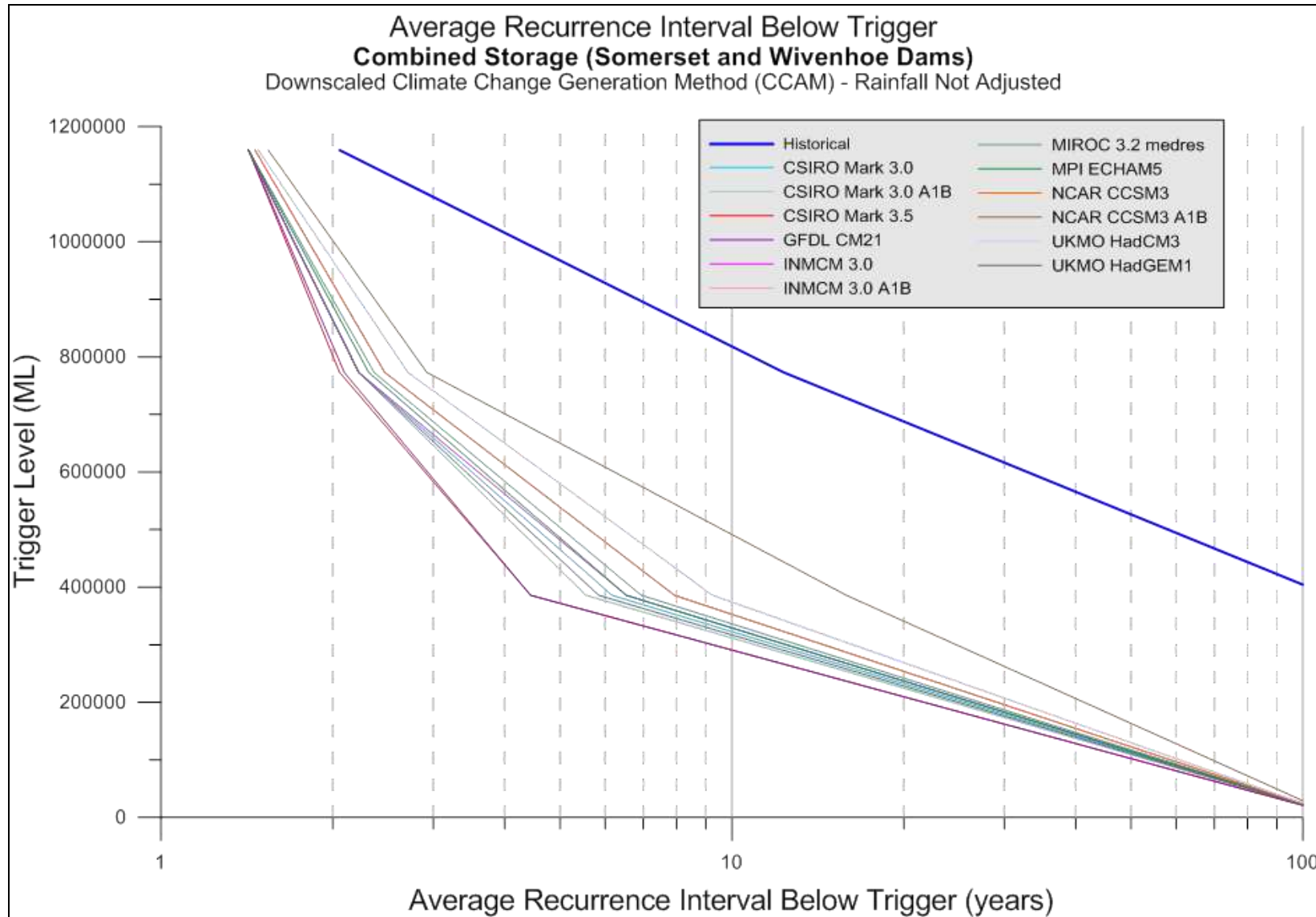


Figure 6.7. Average Recurrence Interval Below Specified Trigger Levels - Combined Wivenhoe and Somerset Dams – Historical and CCAM Climate Model Results (Rainfall Not Adjusted).

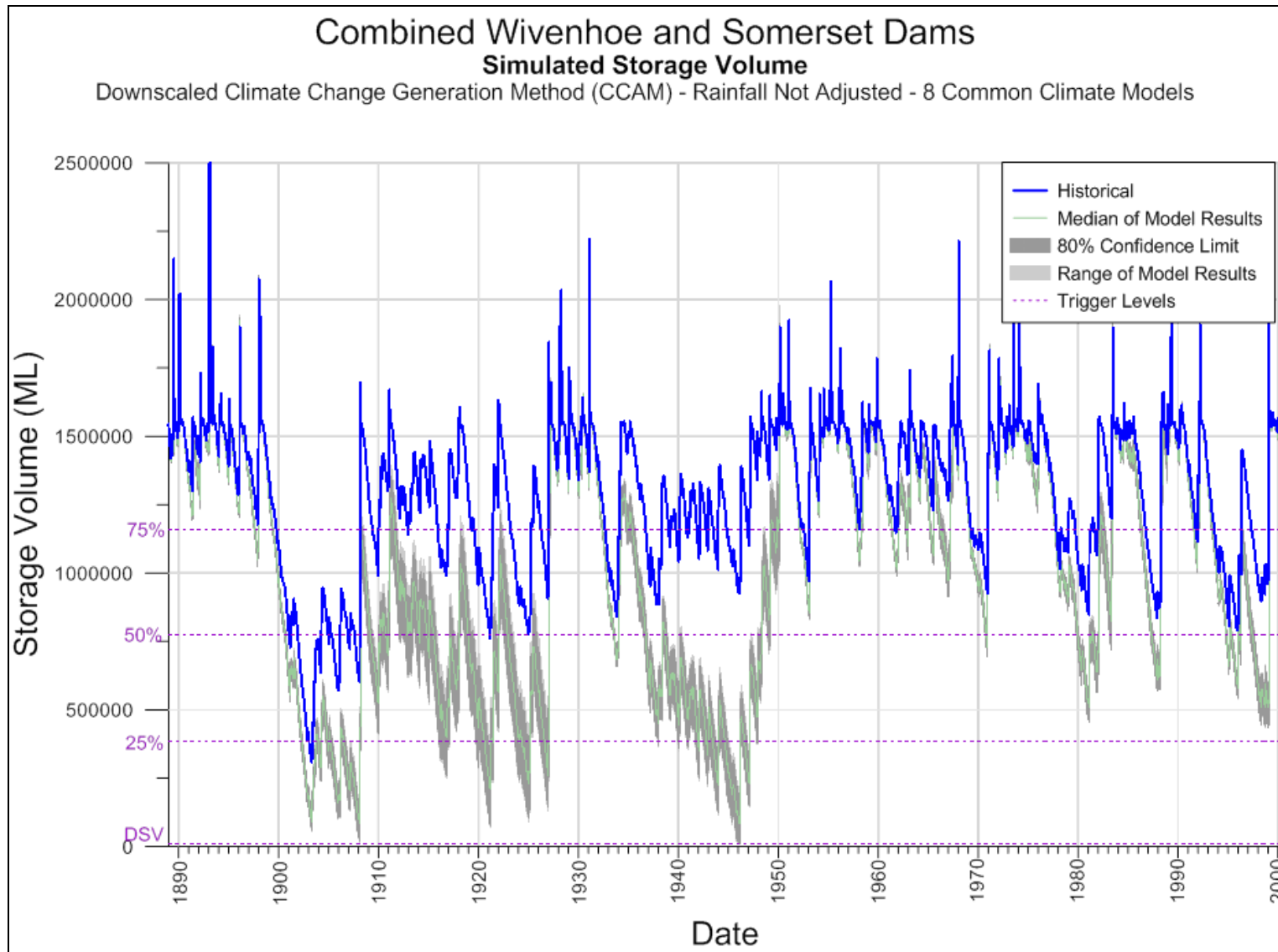


Figure 6.8. Combined Wivenhoe and Somerset Dam Simulated Storage Volume – Historical and Range of CCAM Climate Model Results with Specified Trigger Levels (for 8 common climate models) (Rainfall Not Adjusted).

7. CONCLUSIONS AND RECOMMENDATIONS

High-resolution dynamical downscaling climate model output is showing a further reduction in water availability when compared to the performance of the original GCM climate projections. These reductions are attributed to the spatial and temporal variability, and increased magnitude of the downscaled climate change projections.

The spatial variability of climate change projections has the potential to significantly affect water availability. In this study, the majority of downscaled models show drier projections in the west (inland) of the catchment and wetter projections in the east (towards the coast). This results in reduced inflow to the major storages of Wivenhoe and Somerset Dams, which have a large proportion of the contributing catchment in the areas of drier projections. It is also important to note that the downscaled model projections do not necessarily reflect the behaviour of the original parent GCM. When compared to the original GCM rainfall change projections, the majority of downscaled models show further decreases during the wet summer months, which constitute a large proportion of the catchment inflow. Examination of the monthly percentage change factors for rainfall alone do not give an accurate indication of the impact on inflow due to the insensitivity of changes during the dry winter period as opposed to changes in the wet summer period. The conversion of rainfall to runoff, and consequently to inflow, is also highly sensitive to changes in rainfall.

The decrease in rainfall change factors is accompanied by an increase in evaporation change factors from the downscaled CCAM projections. These increases contribute to reduced runoff generation and faster storage drawdown, affecting the magnitude and duration of droughts. The combined effect of the projected changes to rainfall and evaporation result in significantly reduced inflows to dams and increased time between filling events, and have significant potential implications for planning processes and projects that consider climate change impacts on water supply.

Water availability was assessed by analysing the performance of the combined Wivenhoe and Somerset Dams under each climate change projection. The full sets of both the GCM and CCAM projections resulted in a large range of storage performance, but the majority of CCAM results show a much reduced performance compared to the majority of GCM results. This infers a greater level of certainty in the results from the CCAM projections and indicates that the effect of climate change may be more severe than has been projected by the GCMs.

An additional analysis was conducted to examine the effect of projected changes to evaporation alone, which is consistently shown by all of the models in this study to increase above historic evaporation levels. This analysis assumed no change to historic rainfall, for which there is little consensus among climate models on the magnitude or direction of change. Removing the uncertainty associated with rainfall projections results in more consistent projected impacts on water availability across both the GCM and CCAM data sets. The increased evaporation projections from the downscaled models resulted in an increased frequency of years where available storage volume fell below specific trigger levels.

To examine the effect of downscaling resolution on climate change projections, the GFDL CM-21 GCM was downscaled to ~8km resolution. This provided a direct comparison between the ~20km and ~8km projections. The ~8km resolution projections resulted in significantly reduced inflow and water availability attributed to very large reductions in rainfall and increases in evaporation. Two additional models were run at ~20km and ~8km resolutions to determine whether the extreme projections were the result of model instabilities or initial conditions. These models produced similar results and indicate that it was unlikely that results were affected by such issues. However, the high level of sensitivity to model resolution raises the question of how to choose the optimal or suitable downscaling resolution for hydrologic modelling applications.

Further analysis is required to determine the appropriateness of the methodologies used in this study. Particularly, the method used to derive the climate change factors from the downscaled GCM projections, and the associated issue of using a single model run for each GCM downscaling experiment instead of an ensemble. The perturbed physics experiments conducted for the GFDL CM-21 model also indicate that there may be a high level of uncertainty associated with the projections from a single model run.

APPENDIX A Generation of Climate Change Data

Climate change resulting from anthropogenic CO₂ production can affect water security. This section outlines the approach taken for the incorporation of climate change into data for IQQM modelling. Figure A.1 shows a general schematic of the process used to generate the climate change data from the historical data.

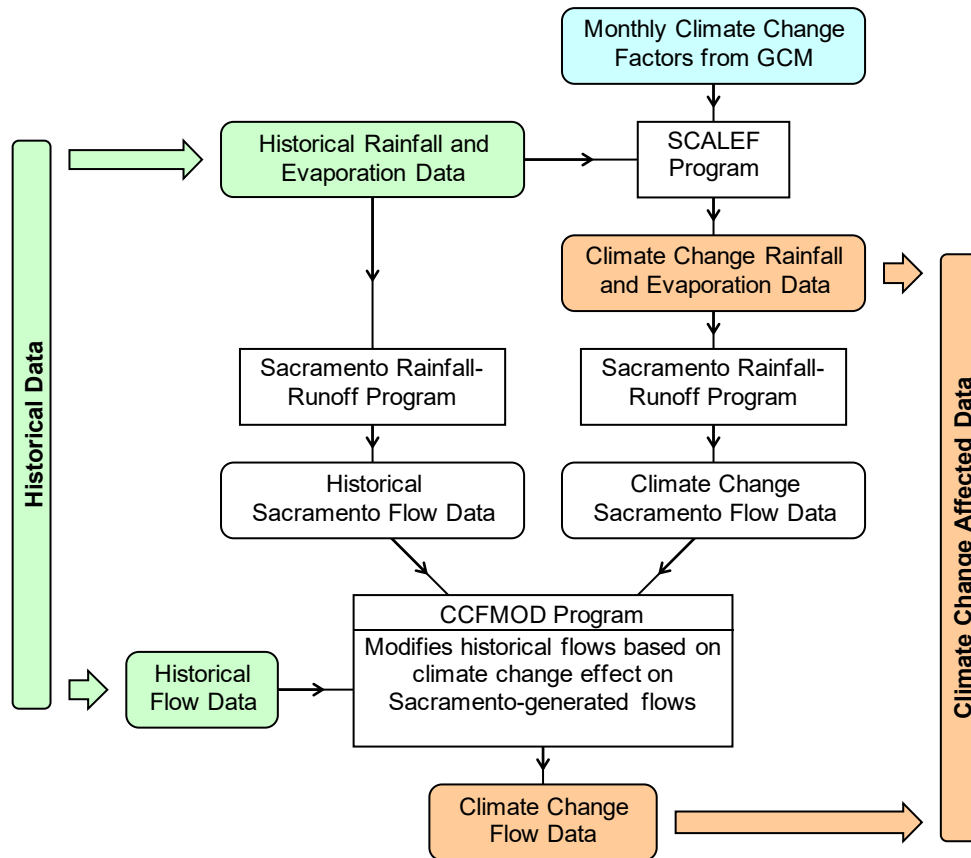


Figure A.1 Schematic for Generation of Daily Climate Change Data for IQQM

A.1 Climate Change Model Percentage Changes

- Evaporation factors are omitted from a number of the climate change models. If this is the case for any of the 3 chosen models, evaporation factors are required to be generated before the models can be applied.
- Firstly, determine the relationship between annual percentage change in temperature and evaporation:
 - For the models which include both temperature and evaporation, the factors for these two parameters should be applied to actual monthly data from the catchment to obtain weighted mean annual values.
 - Comparing the historical weighted mean annual parameter result with the factored mean annual parameter result, will give an annual percentage change for evaporation and temperature for the various climate change models.
 - The annual percentage change of temperature and evaporation can be plotted against each other for a relationship to be determined.

- Calculate the annual percentage change in evaporation for the models which do not include evaporation factors:
 - The annual percentage change in temperature for the models which do not include evaporation should then be calculated using the method described above.
 - The calculated annual temperature change should then be inputted into the relationship between temperature and evaporation; using this method the annual evaporation change for the incomplete models can be determined.
- Convert the yearly change in evaporation to monthly scaling percentages:
 - Compare the annual percentage changes in evaporation for the complete and incomplete models; choose the complete model which has the closest annual percentage evaporation change for each incomplete model and calculate the ratio difference.
 - Use the monthly pattern of the aforementioned chosen model evaporation and multiply each monthly percentage change of evaporation by the calculated ratio. This will result in monthly percentage changes for each incomplete model.

A.2 Generation of Climate Change Evaporation and Rainfall

- Use SCALEF4 (Harding 2008) to scale each rainfall and evaporation series based on monthly climate change percentage variations for each of the three selected models:
 - Write a SCALEF4 input file for each series of rainfall and evaporation (i.e. Scale_R1.in) which contains the name of the original rainfall/evaporation file, the name of the climate change output file, the 12 monthly percentage changes and the monthly seepage (only for some evaporation series). See example below of appropriate scalef4 input file.

oRain_01.iqq	\Name of original file
CC_Rain1.iqq	\Name of climate change output file
-2 -2 -4 -4 -5 -6 -7 -5 -6 -6 -4 -3	\12 monthly percentage changes
0	\Monthly seepage (only for some evaporation series)

- Write a text file for each series of rainfall and evaporation (i.e. Rain_01.txt) which contains the name of the scalef4 input file (i.e. Scale_R1.in), the name of a monthly statistic output file and two “y’s” (this signifies to overwrite the files if they already exist in that directory). See example below of appropriate text file.

scale_r1.in	\Name of the scalef4 input file
month_r1.out	\Monthly statistics output file
y	\Overwrite if file already exists
y	\Overwrite if file already exists

- Write a batch file which runs the SCALEF4 program for each series of rainfall and evaporation (i.e. Generate_CC_Rain_&_Evap.bat). The SCALEF4 program runs and inputs the text files which were previously created; see example below.

```
@echo off
echo.
echo **Generate_CC_Rain_Evap
scalef4 < Rain_01.txt
scalef4 < Rain_02.txt
scalef4 < Evap_01.txt
scalef4 < Evap_02.txt
scalef4 < Evap_03.txt
echo.
pause
```

- The output of this process should be a climate change IQQM file for each series of rainfall and evaporation.

A.3 Generation of Climate Change Flows

- Run all the Sacramento files for the catchment using historical rainfall and evaporation data series.
- Re-run all the Sacramento files for the catchment, this time using the appropriate climate change adjusted rainfall and evaporation files.
- Modify the historical flows to generate climate change flows using the CCFMOD program (Harding 2008); the CCFMOD program looks at the relationship between the historically generated Sacramento flow and the climate change generated Sacramento flow and applies this relationship to the historically recorded flow.
 - Create an input file for CCFMOD which contains the number of files to be modified, the start and end dates, the name of the Sacramento flow file which was generated using historical rainfall and evaporation, the name of the Sacramento flow file generated using climate change rainfall and evaporation, the name of the historical file which is to be modified and the name of the output climate change flow file. If more than one file is to be modified, the name of the next historical file should then be written, followed by the name of its output climate change file and so forth. See example below.

2	\Number of files to be modified
01 07 1890 30 06 1999	\Start and end dates
oFlow_01.iqq	\Historical Sacramento
CC_sacfl.iqq	\Climate change Sacramento
HFlow_01.iqq	\Historical flow to be modified 1
CC_Fl1.iqq	\Output climate change flow 1
HFlow_02.iqq	\Historical flow to be modified 2
CC_Fl2.iqq	\Output climate change flow 2

- For each flow series, a climate change IQQM flow file should be generated as a result of this process.

A.4 Post-Processing of Flows

- Generate periodic flows:
 - Periodic flows do not need to be modified in any way, so using NRW Process (Vitkovsky 2008) the pattern of the periodic flow can be obtained and then the length of data required can be generated from this pattern. See below.

A.5 Discussion

There is a great deal of uncertainty in climate change modelling. Some of these are:

- Uncertainty in GCM – these are the 10th, 50th and 90th percentiles presented.
- Uncertainty in CO₂ projection – shown as difference between A1B and A1FI scenarios.
- Uncertainty from initial conditions in GCM – Not considered.
- Uncertainty from calibration of GCM parameters – Not considered.
- Probably many other sources of uncertainty.

Climate change analysis is in its infancy and many GCMs and generation of data for IQQM are being refined. Some ongoing work will potentially be incorporated in future analyses are:

- GCMs with improved replication of physical processes.
- GCMs that use a finer grid.
- Ensemble GCM output.
- Downscaling analysis (both statistical and dynamic).
- BOM to generate climate change affected rainfall and evaporation data.

APPENDIX B Summary of Climate Change Adjusted Data

B.1 Rainfall

B.1.1 Upper Brisbane

Table 7.1 Summary of Rainfall Data Used in the Upper Brisbane Model

File Number	Description of File	Filename	Climate Change Adjusted	Comments
1	Upper Brisbane Sub-catchment UB1	ub1.pp2	Yes	
2	Upper Brisbane Sub-catchment UB2	ub2.pp2	Yes	
3	Upper Brisbane Sub-catchment UB3	ub3.pp2	Yes	
4	Upper Brisbane Sub-catchment UB4	ub4.pp2	Yes	
5	Upper Brisbane Sub-catchment UB5	ub5.pp2	Yes	
6	Upper Brisbane Sub-catchment UB6	ub6.pp2	Yes	
7	Upper Brisbane Sub-catchment UB7	ub7.pp2	Yes	
8	Upper Brisbane Sub-catchment UB8	ub8.pp2	Yes	
9	Upper Brisbane Sub-catchment UB9	ub9.pp2	Yes	
10	Upper Brisbane Sub-catchment UB10	ub10.pp2	Yes	
11	Upper Brisbane Sub-catchment UB11	ub11.pp2	Yes	
12	Upper Brisbane Sub-catchment UB12	ub12.pp2	Yes	
13	Upper Brisbane Sub-catchment UB13	ub13.pp2	Yes	
14	Upper Brisbane Sub-catchment UB14	ub14.pp2	Yes	
15	Upper Brisbane Sub-catchment UB15	ub15.pp2	Yes	
16	Upper Brisbane Sub-catchment UB16	ub16.pp2	Yes	
17	Upper Brisbane Sub-catchment UB17	ub17.pp2	Yes	
18	Upper Brisbane Sub-catchment UB18	ub18.pp2	Yes	
19	Upper Brisbane Sub-catchment UB19	ub19.pp2	Yes	
20	Upper Brisbane Sub-catchment UB20	ub20.pp2	Yes	
21	Upper Brisbane Sub-catchment UB21	ub21.pp2	Yes	
22	Upper Brisbane Sub-catchment UB22	ub22.pp2	Yes	
23	Upper Brisbane Sub-catchment UB23	ub23.pp2	Yes	
24	Upper Brisbane Sub-catchment UB24	ub24.pp2	Yes	
25	Upper Brisbane Sub-catchment UB25	ub25.pp2	Yes	
26	Upper Brisbane Sub-catchment UB26	ub26.pp2	Yes	
27	Upper Brisbane Sub-catchment UB27	ub27.pp2	Yes	
28	Upper Brisbane Sub-catchment UB28	ub28.pp2	Yes	
29	Upper Brisbane Sub-catchment UB29	ub29.pp2	Yes	
30	Upper Brisbane Sub-catchment UB30	ub30.pp2	Yes	
31	Upper Brisbane Sub-catchment UB31	ub31.pp2	Yes	
32	Upper Brisbane Sub-catchment UB32	ub32.pp2	Yes	
33	Upper Brisbane Sub-catchment UB33	ub33.pp2	Yes	
34	Upper Brisbane Sub-catchment UB34	ub34.pp2	Yes	
35	Upper Brisbane Sub-catchment UB35	ub35.pp2	Yes	
36	Upper Brisbane Sub-catchment UB36	ub36.pp2	Yes	
37	Upper Brisbane Sub-catchment UB37	ub37.pp2	Yes	
38	Upper Brisbane Sub-catchment UB38	ub38.pp2	Yes	
39	Upper Brisbane Sub-catchment UB39	ub39.pp2	Yes	
40	Upper Brisbane Sub-catchment UB40	ub40.pp2	Yes	
41	Upper Brisbane Sub-catchment UB41	ub41.pp2	Yes	
42	Upper Brisbane Sub-catchment UB42	ub42.pp2	Yes	
43	Upper Brisbane Sub-catchment UB43	ub43.pp2	Yes	
44	Upper Brisbane Sub-catchment UB44	ub44.pp2	Yes	
45	Upper Brisbane Sub-catchment UB45	ub45.pp2	Yes	
46	Upper Brisbane Sub-catchment UB46	ub46.pp2	Yes	

File Number	Description of File	Filename	Climate Change Adjusted	Comments
47	Upper Brisbane Sub-catchment UB47	ub47.pp2	Yes	
48	Upper Brisbane Sub-catchment UB48	ub48.pp2	Yes	
49	Upper Brisbane Sub-catchment UB49	ub49.pp2	Yes	
50	Upper Brisbane Sub-catchment UB50	ub50.pp2	Yes	
51	Upper Brisbane Sub-catchment UB51	ub51.pp2	Yes	
52	Upper Brisbane Sub-catchment UB52	ub52.pp2	Yes	
53	Upper Brisbane Sub-catchment UB53	ub53.pp2	Yes	
54	Upper Brisbane Sub-catchment UB54	ub54.pp2	Yes	
55	Upper Brisbane Sub-catchment UB55	ub55.pp2	Yes	
56	Upper Brisbane Sub-catchment UB56	ub56.pp2	Yes	
57	Upper Brisbane Sub-catchment UB57	ub57.pp2	Yes	
58	Upper Brisbane Sub-catchment UB58	ub58.pp2	Yes	
59	Upper Brisbane Sub-catchment UB59	ub59.pp2	Yes	
60	Upper Brisbane Sub-catchment UB60	ub60.pp2	Yes	
61	Upper Brisbane Sub-catchment UB61	ub61.pp2	Yes	
62	Upper Brisbane Sub-catchment UB62	ub62.pp2	Yes	
63	Upper Brisbane Sub-catchment UB63	ub63.pp2	Yes	
64	Upper Brisbane Sub-catchment UB64	ub64.pp2	Yes	
65	Upper Brisbane Sub-catchment UB65	ub65.pp2	Yes	
66	Upper Brisbane Sub-catchment UB66	ub66.pp2	Yes	
67	Upper Brisbane Sub-catchment UB67	ub67.pp2	Yes	
68	Upper Brisbane Sub-catchment UB68	ub68.pp2	Yes	
69	Upper Brisbane Sub-catchment UB69	ub69.pp2	Yes	
70	Upper Brisbane Sub-catchment UB70	ub70.pp2	Yes	
71	Upper Brisbane Sub-catchment UB71	ub71.pp2	Yes	
72	Upper Brisbane Sub-catchment UB72	ub72.pp2	Yes	
73	Upper Brisbane Sub-catchment UB73	ub73.pp2	Yes	
74	Upper Brisbane Sub-catchment UB74	ub74.pp2	Yes	
75	Upper Brisbane Sub-catchment UB75	ub75.pp2	Yes	
76	Upper Brisbane Sub-catchment UB76	ub76.pp2	Yes	
77	Upper Brisbane Sub-catchment UB77	ub77.pp2	Yes	
78	Upper Brisbane Sub-catchment UB78	ub78.pp2	Yes	
79	Combination of Rainfall Files	rain1.pp2	Post processed	Reach 1 Addition of rainfall files ub7 + ub8 + ... + ub19
80	Combination of Rainfall Files	Rain2.pp2	Post processed	Reach 2 Addition of rainfall files ub1 + ub2 + ... + ub6 + ub20 + ub21 + ... + ub32
81	Combination of Rainfall Files	rain3.pp2	Post processed	Reach 3 Addition of rainfall files ub38 + ub39 + ... + ub43
82	Combination of Rainfall Files	rain4.pp2	Post processed	Reach 4 Addition of rainfall files ub44 + ub45 + ... + ub50
83	Combination of Rainfall Files	rain5.pp2	Post processed	Reach 5 Addition of rainfall files ub33 + ub34 + ... + ub37 + ub51 + ub52 + ... + ub63
84	Combination of Rainfall Files	rain6.pp2	Post processed	Reach 6 Addition of rainfall files ub66 + ub67 + ... + ub70
85	Combination of Rainfall Files	rain7.pp2	Post processed	Reach 7 Addition of rainfall files ub71 + ub72 + ... + ub75
86	Combination of Rainfall Files	rain8.pp2	Post processed	Reach 8 Addition of rainfall files ub64 + ub65 + ub76 + ub77 + ub78

B.1.2 Lockyer

Table 7.2 Summary of Rainfall Data Used in the Lockyer Model

File Number	Description of File	Filename	Climate Change Adjusted	Comments
1	Lockyer Sub-catchment L11	L11.pp2	Yes	
2	Lockyer Sub-catchment L12	L12.pp2	Yes	
3	Lockyer Sub-catchment L19	L19.pp2	Yes	
4	Lockyer Sub-catchment L27	L27.pp2	Yes	
5	Lockyer Sub-catchment L31	L31.pp2	Yes	
6	Lockyer Sub-catchment L32	L32.pp2	Yes	
7	Lockyer Sub-catchment L10	L10.pp2	Yes	
8	Lockyer Sub-catchment L17	L17.pp2	Yes	
9	Lockyer Sub-catchment L26	L26.pp2	Yes	
10	Lockyer Sub-catchment L35	L35.pp2	Yes	
11	Lockyer Sub-catchment L38	L38.pp2	Yes	
12	Lockyer Sub-catchment L37	L37.pp2	Yes	
13	Lockyer Sub-catchment L40	L40.pp2	Yes	
14	Lockyer Sub-catchment L42	L42.pp2	Yes	
15	Lockyer Sub-catchment L45	L45.pp2	Yes	
16	Lockyer Sub-catchment L30	L30.pp2	Yes	
17	Lockyer Sub-catchment L52	L52.pp2	Yes	
18	Lockyer Sub-catchment L57	L57.pp2	Yes	
19	Lockyer Sub-catchment L55	L55.pp2	Yes	
20	Combination of Rainfall Files	rain14.pp2	Post processed	Reach 14 Addition of rainfall files I2 + I3 + ... + I6
21	Combination of Rainfall Files	rain15.pp2	Post processed	Reach 15 Addition of rainfall files I9 + I10
22	Combination of Rainfall Files	rain16.pp2	Post processed	Reach 16 Addition of rainfall files I14 + I15 + ... + I17
23	Combination of Rainfall Files	rain17.pp2	Post processed	Reach 17 Addition of rainfall files I20 + I21 + ... + I26
24	Combination of Rainfall Files	rain18.pp2	Post processed	Reach 18 Addition of rainfall files I7 + I8 + I11 + I12 + I13 + I18 + I19 + I27 + I28 + I31
25	Combination of Rainfall Files	rain19.pp2	Post processed	Reach 19 Addition of rainfall files I33 + I34 + I35 + I36
26	Combination of Rainfall Files	rain20.pp2	Post processed	Reach 20 Addition of rainfall files I32 + I37 + I38 + ... + I43 + I45 + I46 + ... + I49
27	Combination of Rainfall Files	rain21.pp2	Post processed	Reach 21 Addition of rainfall files I50 + I51 + I52
28	Combination of Rainfall Files	ND1.PP2	Post processed	ND1 Addition of rainfall files I6 + I7 + I8
29	Combination of Rainfall Files	ND2.PP2	Post processed	ND2 Addition of rainfall files I12 + I13
30	Lockyer Sub-catchment L19	ND3.PP2	Yes	ND3 Same as I19
31	Lockyer Sub-catchment L28	ND4.PP2	Yes	ND4 Same as I28
32	Combination of Rainfall Files	ND5.PP2	Post processed	ND5 Addition of rainfall files I30 + I31
33	Combination of Rainfall Files	ND6.PP2	Post processed	ND6 Addition of rainfall files I30 + I31
34	Lockyer Sub-catchment L11	ND15.PP2	Yes	ND15 Same as I11
35	Lockyer Sub-catchment L27	ND19.PP2	Yes	ND19 Same

File Number	Description of File	Filename	Climate Change Adjusted	Comments
				as I27
36	Lockyer Sub-catchment L43	L43.pp2	Yes	
37	Lockyer Sub-catchment L56	L56.pp2	Yes	
38	Combination of Rainfall Files	ND26.PP2	Post processed	ND26 Addition of rainfall files I29 + I30
39	Dummy File	dummy.rn	No	Dummy file - 0mm/d

B.1.3 Bremer

Table 7.3 Summary of Rainfall Data Used in the Bremer Model

File Number	Description of File	Filename	Climate Change Adjusted	Comments
1	Moogerah Dam site (stn: 040135) rainfall	MOOGERAH.Rnf	Yes	
2	Dummy File	dummy.rn	No	Dummy file - 0mm/d
3	Dummy File	dummy.rn	No	Dummy file - 0mm/d
4	Bremer Sub-catchment B4	B4.pp2	Yes	
5	Bremer Sub-catchment B5	B5.pp2	Yes	
6	Bremer Sub-catchment B6	B6.pp2	Yes	
7	Bremer Sub-catchment B7	B7.pp2	Yes	
8	Bremer Sub-catchment B8	B8.pp2	Yes	
9	Bremer Sub-catchment B9	B9.pp2	Yes	
10	Bremer Sub-catchment B10	B10.pp2	Yes	
11	Bremer Sub-catchment B11	B11.pp2	Yes	
12	Bremer Sub-catchment B12	B12.pp2	Yes	
13	Bremer Sub-catchment B13	B13.pp2	Yes	
14	Bremer Sub-catchment B14	B14.pp2	Yes	
15	Bremer Sub-catchment B15	B15.pp2	Yes	
16	Bremer Sub-catchment B16	B16.pp2	Yes	
17	Bremer Sub-catchment B17	B17.pp2	Yes	
18	Bremer Sub-catchment B18	B18.pp2	Yes	
19	Bremer Sub-catchment B19	B19.pp2	Yes	
20	Bremer Sub-catchment B20	B20.pp2	Yes	
21	Bremer Sub-catchment B21	B21.pp2	Yes	
22	Bremer Sub-catchment B22	B22.pp2	Yes	
23	Bremer Sub-catchment B23	B23.pp2	Yes	
24	Bremer Sub-catchment B24	B24.pp2	Yes	
25	Bremer Sub-catchment B25	B25.pp2	Yes	
26	Bremer Sub-catchment B26	B26.pp2	Yes	
27	Bremer Sub-catchment B27	B27.pp2	Yes	
28	Bremer Sub-catchment B28	B28.pp2	Yes	
29	Bremer Sub-catchment B29	B29.pp2	Yes	
30	Bremer Sub-catchment B30	B30.pp2	Yes	
31	Bremer Sub-catchment B31	B31.pp2	Yes	
32	Bremer Sub-catchment B32	B32.pp2	Yes	
33	Bremer Sub-catchment B33	B33.pp2	Yes	
34	Bremer Sub-catchment B34	B34.pp2	Yes	
35	Bremer Sub-catchment B35	B35.pp2	Yes	
36	Bremer Sub-catchment B36	B36.pp2	Yes	
37	Bremer Sub-catchment B37	B37.pp2	Yes	
38	Bremer Sub-catchment B38	B38.pp2	Yes	
39	Dummy File	dummy.rn	No	Dummy file - 0mm/d

B.1.4 Stanley, Central Brisbane and Lower Brisbane

Table 7.4 Summary of Rainfall Data Used in the Stanley, Central Brisbane and Lower Brisbane Model

File Number	Description of File	Filename	Climate Change Adjusted	Comments
1	Stanley Sub-catchment S1	s1.pp2	Yes	
2	Stanley Sub-catchment S2	s2.pp2	Yes	
3	Stanley Sub-catchment S3	s3.pp2	Yes	
4	Stanley Sub-catchment S4	s4.pp2	Yes	
5	Stanley Sub-catchment S5	s5.pp2	Yes	
6	Stanley Sub-catchment S6	s6.pp2	Yes	
7	Stanley Sub-catchment S7	s7.pp2	Yes	
8	Stanley Sub-catchment S8	s8.pp2	Yes	
9	Stanley Sub-catchment S9	s9.pp2	Yes	
10	Stanley Sub-catchment S10	s10.pp2	Yes	
11	Stanley Sub-catchment S11	s11.pp2	Yes	
12	Stanley Sub-catchment S12	s12.pp2	Yes	
13	Stanley Sub-catchment S13	s13.pp2	Yes	
14	Stanley Sub-catchment S14	s14.pp2	Yes	
15	Stanley Sub-catchment S15	s15.pp2	Yes	
16	Stanley Sub-catchment S16	s16.pp2	Yes	
17	Stanley Sub-catchment S17	s17.pp2	Yes	
18	Stanley Sub-catchment S18	s18.pp2	Yes	
19	Stanley Sub-catchment S19	s19.pp2	Yes	
20	Stanley Sub-catchment S20	s20.pp2	Yes	
21	Stanley Sub-catchment S21	s21.pp2	Yes	
22	Central Brisbane Sub-catchment CB1	cb1.pp2	Yes	
23	Central Brisbane Sub-catchment CB2	cb2.pp2	Yes	
24	Central Brisbane Sub-catchment CB3	cb3.pp2	Yes	
25	Central Brisbane Sub-catchment CB4	cb4.pp2	Yes	
26	Central Brisbane Sub-catchment CB5	cb5.pp2	Yes	
27	Central Brisbane Sub-catchment CB6	cb6.pp2	Yes	
28	Central Brisbane Sub-catchment CB7	cb7.pp2	Yes	
29	Central Brisbane Sub-catchment CB8	cb8.pp2	Yes	
30	Central Brisbane Sub-catchment CB9	cb9.pp2	Yes	
31	Central Brisbane Sub-catchment CB10	cb10.pp2	Yes	
32	Central Brisbane Sub-catchment CB11	cb11.pp2	Yes	
33	Central Brisbane Sub-catchment CB12	cb12.pp2	Yes	
34	Central Brisbane Sub-catchment CB13	cb13.pp2	Yes	
35	Lower Brisbane Sub-catchment LB1	lb1.pp2	Yes	
36	Lower Brisbane Sub-catchment LB2	lb2.pp2	Yes	
37	Lower Brisbane Sub-catchment LB3	lb3.pp2	Yes	
38	Lower Brisbane Sub-catchment LB4	lb4.pp2	Yes	
39	Lower Brisbane Sub-catchment LB5	lb5.pp2	Yes	
40	Lower Brisbane Sub-catchment LB6	lb6.pp2	Yes	
41	Lower Brisbane Sub-catchment LB7	lb7.pp2	Yes	
42	Lower Brisbane Sub-catchment LB8	lb8-06b.ppt	Yes	
43	Lower Brisbane Sub-catchment LB9	lb9.pp2	Yes	
44	Lower Brisbane Sub-catchment LB10	lb10.pp2	Yes	
45	Lower Brisbane Sub-catchment LB11	lb11.pp2	Yes	
46	Lower Brisbane Sub-catchment LB12	lb12.pp2	Yes	
47	Lower Brisbane Sub-catchment LB13	lb13.pp2	Yes	
48	Lower Brisbane Sub-catchment LB14	lb14.pp2	Yes	
49	Lower Brisbane Sub-catchment LB15	lb15.pp2	Yes	

File Number	Description of File	Filename	Climate Change Adjusted	Comments
50	Lower Brisbane Sub-catchment LB16	lb16.pp2	Yes	
51	Gold Creek Dam LB17A	lb17a-6b.pp2	Yes	
52	Lower Brisbane Sub-catchment LB18	lb18.pp2	Yes	
53	Lower Brisbane Sub-catchment LB19	lb19.pp2	Yes	
54	Lower Brisbane Sub-catchment LB20	lb20.pp2	Yes	
55	Lower Brisbane Sub-catchment LB21	lb21.pp2	Yes	
56	Lower Brisbane Sub-catchment LB22	lb22.pp2	Yes	
57	Lower Brisbane Sub-catchment LB23	lb23.pp2	Yes	
58	Lower Brisbane Sub-catchment LB24	lb24.pp2	Yes	
59	Lower Brisbane Sub-catchment LB25	lb25.pp2	Yes	
60	Lower Brisbane Sub-catchment LB26	lb26.pp2	Yes	
61	Lower Brisbane Sub-catchment LB27	lb27.pp2	Yes	
62	Lower Brisbane Sub-catchment LB28	lb28.pp2	Yes	
63	Lower Brisbane Sub-catchment LB29	lb29.pp2	Yes	
64	Lower Brisbane Sub-catchment LB30	lb30.pp2	Yes	
65	Lower Brisbane Sub-catchment LB31	lb31.pp2	Yes	
66	Lower Brisbane Sub-catchment LB32	lb32.pp2	Yes	
67	Lower Brisbane Sub-catchment LB33	lb33.pp2	Yes	
68	Lower Brisbane Sub-catchment LB34	lb34.pp2	Yes	
69	Lower Brisbane Sub-catchment LB35	lb35.pp2	Yes	
70	Lower Brisbane Sub-catchment LB36	lb36-06b.ppt	Yes	
71	Lower Brisbane Sub-catchment LB37	lb37-06b.pp2	Yes	
72	Lower Brisbane Sub-catchment LB38	lb38-06b.pp2	Yes	
73	Lower Brisbane Sub-catchment LB39	lb39-06b.pp2	Yes	
74	Lower Brisbane Sub-catchment LB40	lb40-06b.pp2	Yes	
75	Lower Brisbane Sub-catchment LB41	lb41-06b.pp2	Yes	
76	Lower Brisbane Sub-catchment LB42	lb42.pp2	Yes	
77	Lower Brisbane Sub-catchment LB43	lb43.pp2	Yes	
78	Lower Brisbane Sub-catchment LB44	lb44.pp2	Yes	
79	Lower Brisbane Sub-catchment LB45	lb45.pp2	Yes	
80	Lower Brisbane Sub-catchment LB46	lb46.pp2	Yes	
81	Lower Brisbane Sub-catchment LB47	lb47.pp2	Yes	
82	Lower Brisbane Sub-catchment LB48	lb48.pp2	Yes	
83	Lower Brisbane Sub-catchment LB49	lb49.pp2	Yes	
84	Lower Brisbane Sub-catchment LB50	lb50.pp2	Yes	
85	Lower Brisbane Sub-catchment LB51	lb51.pp2	Yes	
86	Combination of Rainfall Files	rain10.PP2	Post processed	Addition of rainfall files s2 + s3 + ... + s21
87	Combination of Rainfall Files	lb2to3_N.pp2	Post processed	Addition of rainfall files lb2 + lb3
88	Lake Manchester Point Rainfall	lakeman.ppt	Yes	
89	Dummy File	dummy.flo	No	Dummy file - 0mm/d

B.2 Evaporation

B.2.1 Upper Brisbane

Table 7.5 Summary of Evaporation Data Used in the Upper Brisbane Model

File Number	Description of File	Filename	Climate Change Adjusted	Comments
1	Gatton PET	40082_wd.pe2	Yes	
2	Gatton lake evaporation and seepage	40082_wd.la2	Yes	Lake evaporation with 25mm/month seepage
3	Brisbane PET	BRIS_WD.PE2	Yes	
4	Brisbane lake evaporation and seepage	BRIS_WD.LA2	Yes	Lake evaporation with 25mm/month seepage
5	Dummy File	dummy.evp	No	Dummy file - 10mm/d
6	Dummy File	cap.evp	No	Dummy file - 100mm for one day a month

B.2.2 Lockyer

Table 7.6 Summary of Evaporation Data Used in the Lockyer Model

File Number	Description of File	Filename	Climate Change Adjusted	Comments
1	Gatton PET	40082_wd.pe2	Yes	
2	Gatton lake evaporation and seepage	40082_wd.la2	Yes	Lake evaporation with 25mm/month seepage
3	Brisbane PET	BRIS_WD.PE2	Yes	
4	Brisbane lake evaporation and seepage	BRIS_WD.LA2	Yes	Lake evaporation with 25mm/month seepage
5	Dummy File	pseudo.evp	No	Dummy file - 10mm/d
6	Dummy File	dummy1.out	No	Dummy - 10,000mm for one day a month

B.2.3 Bremer

Table 7.7 Summary of Evaporation Data Used in the Bremer Model

File Number	Description of File	Filename	Climate Change Adjusted	Comments
1	Gatton PET	040082.pe3	Yes	
2	Gatton lake evaporation and seepage	040082.la3	Yes	Lake evaporation with 25mm/month seepage
3	Brisbane regional PET	040214.pe3	Yes	
4	Brisbane regional lake evaporation and seepage	040214.la3	Yes	Lake evaporation with 25mm/month seepage
5	Lake Moogerah adjusted evaporation	Moog_EVP.Adj	Post processed	Evaporation Adjusted
6	Dummy File	Pseudo10.EVP	No	Dummy file - 10mm/d

B.2.4 Stanley, Central Brisbane and Lower Brisbane

Table 7.8 Summary of Evaporation Data Used in the Stanley, Central Brisbane and Lower Brisbane Model

File Number	Description of File	Filename	Climate Change Adjusted	Comments
1	Gatton PET	40082_wd.pe2	Yes	
2	Gatton lake evaporation and seepage	40082_wd.la2	Yes	Lake evaporation with 25mm/month seepage
3	Brisbane PET	BRIS_WD.PE2	Yes	
4	Brisbane lake evaporation and seepage	BRIS_WD.LA2	Yes	Lake evaporation with 25mm/month seepage
5	Dummy File	pseudo.evp	No	Dummy file - 10mm/d
6	Brisbane regional lake evaporation and seepage	40214_6b.lk4	Yes	Lake evaporation with 25mm/month seepage
7	Dummy File	dummy1.out	No	Dummy - 10,000mm on last day of month.

B.3 Streamflow

B.3.1 Upper Brisbane

Table 7.9 Summary of Streamflow Data Used in the Upper Brisbane Model

File Number	Description of File	Filename	Climate Change Adjusted	Comments
1	Sub-catchment UB1	UB1.s00	Yes	
2	Sub-catchment UB2	UB2.s00	Yes	
3	Sub-catchment UB3	UB3.s00	Yes	
4	Sub-catchment UB4	UB4.s00	Yes	
5	Sub-catchment UB5	UB5.s00	Yes	
6	Sub-catchment UB6	UB6.s00	Yes	
7	Sub-catchment UB7	UB7.s00	Yes	
8	Sub-catchment UB8	UB8.s00	Yes	
9	Sub-catchment UB9	UB9.s00	Yes	
10	Sub-catchment UB10	UB10.s00	Yes	
11	Sub-catchment UB11	UB11.s00	Yes	
12	Sub-catchment UB12	UB12.s00	Yes	
13	Sub-catchment UB13	UB13.s00	Yes	
14	Sub-catchment UB14	UB14.s00	Yes	
15	Sub-catchment UB15	UB15.s00	Yes	
16	Sub-catchment UB16	UB16.s00	Yes	
17	Sub-catchment UB17	UB17.s00	Yes	
18	Sub-catchment UB18	UB18.s00	Yes	
19	Sub-catchment UB19	UB19.s00	Yes	
20	Sub-catchment UB20	UB20.s00	Yes	
21	Sub-catchment UB21	UB21.s00	Yes	
22	Sub-catchment UB22	UB22.s00	Yes	
23	Sub-catchment UB23	UB23.s00	Yes	
24	Sub-catchment UB24	UB24.s00	Yes	
25	Sub-catchment UB25	UB25.s00	Yes	
26	Sub-catchment UB26	UB26.s00	Yes	
27	Sub-catchment UB27	UB27.s00	Yes	
28	Sub-catchment UB28	UB28.s00	Yes	
29	Sub-catchment UB29	UB29.s00	Yes	
30	Sub-catchment UB30	UB30.s00	Yes	
31	Sub-catchment UB31	UB31.s00	Yes	
32	Sub-catchment UB32	UB32.s00	Yes	
33	Sub-catchment UB33	UB33.s00	Yes	
34	Sub-catchment UB34	UB34.s00	Yes	
35	Sub-catchment UB35	UB35.s00	Yes	
36	Sub-catchment UB36	UB36.s00	Yes	
37	Sub-catchment UB37	UB37.s00	Yes	
38	Sub-catchment UB38	UB38.s00	Yes	
39	Sub-catchment UB39	UB39.s00	Yes	
40	Sub-catchment UB40	UB40.s00	Yes	
41	Sub-catchment UB41	UB41.s00	Yes	
42	Sub-catchment UB42	UB42.s00	Yes	
43	Sub-catchment UB43	UB43.s00	Yes	
44	Sub-catchment UB44	UB44.s00	Yes	
45	Sub-catchment UB45	UB45.s00	Yes	
46	Sub-catchment UB46	UB46.s00	Yes	
47	Sub-catchment UB47	UB47.s00	Yes	
48	Sub-catchment UB48	UB48.s00	Yes	
49	Sub-catchment UB49	UB49.s00	Yes	

File Number	Description of File	Filename	Climate Change Adjusted	Comments
50	Sub-catchment UB50	UB50.s00	Yes	
51	Sub-catchment UB51	UB51.s00	Yes	
52	Sub-catchment UB52	UB52.s00	Yes	
53	Sub-catchment UB53	UB53.s00	Yes	
54	Sub-catchment UB54	UB54.s00	Yes	
55	Sub-catchment UB55	UB55.s00	Yes	
56	Sub-catchment UB56	UB56.s00	Yes	
57	Sub-catchment UB57	UB57.s00	Yes	
58	Sub-catchment UB58	UB58.s00	Yes	
59	Sub-catchment UB59	UB59.s00	Yes	
60	Sub-catchment UB60	UB60.s00	Yes	
61	Sub-catchment UB61	UB61.s00	Yes	
62	Sub-catchment UB62	UB62.s00	Yes	
63	Sub-catchment UB63	UB63.s00	Yes	
64	Sub-catchment UB64	UB64.s00	Yes	
65	Sub-catchment UB65	UB65.s00	Yes	
66	Sub-catchment UB66	UB66.s00	Yes	
67	Sub-catchment UB67	UB67.s00	Yes	
68	Sub-catchment UB68	UB68.s00	Yes	
69	Sub-catchment UB69	UB69.s00	Yes	
70	Sub-catchment UB70	UB70.s00	Yes	
71	Sub-catchment UB71	UB71.s00	Yes	
72	Sub-catchment UB72	UB72.s00	Yes	
73	Sub-catchment UB73	UB73.s00	Yes	
74	Sub-catchment UB74	UB74.s00	Yes	
75	Sub-catchment UB75	UB75.s00	Yes	
76	Sub-catchment UB76	UB76.s00	Yes	
77	Sub-catchment UB77	UB77.s00	Yes	
78	Sub-catchment UB78	UB78.s00	Yes	
79	Factored Rainfall File	recharge.flo	Post processed	Rainfall ub74.pp2 factored by 0.44
80	Factored Rainfall File	Recharg1.FLO	Post processed	Rainfall ub76.pp2 factored by 0.35
81	Factored Rainfall File	Recharg2.FLO	Post processed	Rainfall ub76.pp2 factored by 1.79
82	Riparian Releases	riparian.rel	No	Riparian releases or similar
83	Riparian Releases	cres_rip.flo	No	Riparian releases or similar
84	TWS Yarraman	ted.dif	No	TWS diversions
85	TWS BlackbuttA	boob.dif	No	TWS diversions
86	TWS Nanango	mcca.dif	No	TWS diversions
87	TWS BlackbuttB	taro.dif	No	TWS diversions
88	Reg Irr UB76	ub76.dif	No	TWS diversions
89	Dummy File	dummy.flo	No	Dummy file - 0ML/d
90	Dummy File	big.flo	No	Dummy file - 1,000ML/d

B.3.2 Lockyer

Table 7.10 Summary of Streamflow Data Used in the Lockyer Model

File Number	Description of File	Filename	Climate Change Adjusted	Comments
1	Sub-catchment L1	L1.S01	Yes	
2	Sub-catchment L2	L2.S01	Yes	
3	Sub-catchment L3	L3.S01	Yes	
4	Sub-catchment L4	L4.S01	Yes	
5	Sub-catchment L5	L5.S01	Yes	
6	Sub-catchment L6	L6.S01	Yes	
7	Sub-catchment L7	L7.S01	Yes	
8	Sub-catchment L8	L8.S01	Yes	
9	Sub-catchment L9	L9.S01	Yes	
10	Sub-catchment L10	L10.S01	Yes	
11	Sub-catchment L11	L11.S01	Yes	
12	Sub-catchment L12	L12.S01	Yes	
13	Sub-catchment L13	L13.S01	Yes	
14	Sub-catchment L14	L14.S01	Yes	
15	Sub-catchment L15	L15.S01	Yes	
16	Sub-catchment L16	L16.S01	Yes	
17	Sub-catchment L17	L17.S01	Yes	
18	Sub-catchment L18	L18.S01	Yes	
19	Sub-catchment L19	L19.S01	Yes	
20	Sub-catchment L20	L20.S01	Yes	
21	Sub-catchment L21	L21.S01	Yes	
22	Sub-catchment L22	L22.S01	Yes	
23	Sub-catchment L23	L23.S01	Yes	
24	Sub-catchment L24	L24.S01	Yes	
25	Sub-catchment L25	L25.S01	Yes	
26	Sub-catchment L26	L26.S01	Yes	
27	Sub-catchment L27	L27.S01	Yes	
28	Sub-catchment L28	L28.S01	Yes	
29	Sub-catchment L29	L29.S01	Yes	
30	Sub-catchment L30	L30.S01	Yes	
31	Sub-catchment L31	L31.S01	Yes	
32	Sub-catchment L32	L32.S01	Yes	
33	Sub-catchment L33	L33.S01	Yes	
34	Sub-catchment L34	L34.S01	Yes	
35	Sub-catchment L35	L35.S01	Yes	
36	Sub-catchment L36	L36.S01	Yes	
37	Sub-catchment L37	L37.S01	Yes	
38	Sub-catchment L38	L38.S01	Yes	
39	Sub-catchment L39	L39.S01	Yes	
40	Sub-catchment L40	L40.S01	Yes	
41	Sub-catchment L41	L41.S01	Yes	
42	Sub-catchment L42	L42.S01	Yes	
43	Sub-catchment L43	L43A.S01	Yes	
44	Sub-catchment L43	L43B.S01	Yes	
45	Sub-catchment L45	L45A.S01	Yes	
46	Sub-catchment L45	L45B.S01	Yes	
47	Sub-catchment L46	L46.S01	Yes	
48	Sub-catchment L47	L47.S01	Yes	
49	Sub-catchment L48	L48.S01	Yes	
50	Sub-catchment L49	L49.S01	Yes	
51	Sub-catchment L50	L50.S01	Yes	

File Number	Description of File	Filename	Climate Change Adjusted	Comments
52	Sub-catchment L51	L51.S01	Yes	
53	Sub-catchment L52	L52.S01	Yes	
54	Sub-catchment L53	L53.S01	Yes	
55	Sub-catchment L54	L4455.dec	Yes	
56	Sub-catchment L55	L54.S01	Yes	
57	Sub-catchment L56	I56.S01	Yes	
58	Sub-catchment L57	I57.S01	Yes	
59	Factored Rainfall File	ND1_FLO.INF	Post processed	Rainfall nd1.pp2 factored by 0.871
60	Factored Rainfall File	ND2_FLO.inf	Post processed	Rainfall nd2.pp2 factored by 0.607
61	Factored Rainfall File	ND3_FLO.inf	Post processed	Rainfall nd3.pp2 factored by 0.932
62	Dummy File	ND4_FLO.inf	No	Dummy file - 0ML/d
63	Dummy File	ND5_FLO.inf	No	Dummy file - 0ML/d
64	Dummy File	ND6_FLO.inf	No	Dummy file - 0ML/d
65	Factored Rainfall File	nd10_flo.inf	Post processed	Rainfall nd10.pp2 factored by 1.048
66	Factored Rainfall File	nd11_flo.inf	Post processed	Rainfall I57.pp2 factored by 0.941
67	Factored Rainfall File	nd12_flo.inf	Post processed	Rainfall I57.pp2 factored by 1.321
68	Factored Rainfall File	nd13_flo.inf	Post processed	Rainfall I56.pp2 factored by 0.371
69	Factored Rainfall File	nd14_flo.inf	Post processed	Rainfall nd14.pp2 factored by 0.239
70	Factored Rainfall File	ND15_FLO.inf	Post processed	Rainfall nd15.pp2 factored by 0.302
71	Factored Rainfall File	nd16_flo.inf	Post processed	Rainfall nd16.pp2 factored by 0.156
72	Factored Rainfall File	nd17_flo.inf	Post processed	Rainfall nd17.pp2 factored by 0.372
73	Factored Rainfall File	ND18_FLO.inf	Post processed	Rainfall nd18.pp2 factored by 0.451
74	Factored Rainfall File	ND19_FLO.inf	Post processed	Rainfall nd19.pp2 factored by 0.503
75	Factored Rainfall File	nd20_flo.inf	Post processed	Rainfall nd20.pp2 factored by 0.248
76	Factored Rainfall File	ND21_FLO.INF	Post processed	Rainfall nd21.pp2 factored by 0.487
77	Factored Rainfall File	nd22_flo.inf	Post processed	Rainfall nd22.pp2 factored by 0.594
78	Factored Rainfall File	ND26_FLO.inf	Post processed	Rainfall nd26.pp2 factored by 0.056
79	Calibration File	CLAR_REL.flw	No	Calibration files
80	Dummy File	big.flo	No	Dummy file - 1,000ML/d
81	Calibration File	dyeR_OUT.IQM	No	Calibration files
82	Calibration File	atkinson.rel	No	Calibration files
83	Calibration File	clar_wh.dem	No	Calibration files
84	Calibration File	br_chan.iqm	No	Calibration files
85	Calibration File	b2_divr.iq2	No	Calibration files
86	Demand patch	L3106.dif	No	Demand patch
87	Demand patch	L3206.dif	No	Demand patch
88	Demand patch	37806.dif	No	Demand patch
89	Demand patch	L4206.dif	No	Demand patch
90	Demand patch	45A06.dif	No	Demand patch
91	Demand patch	45B06.dif	No	Demand patch
92	Demand patch	L4606.dif	No	Demand patch
93	Demand patch	L4706.dif	No	Demand patch
94	Demand patch	L4806.dif	No	Demand patch
95	Demand patch	L4906.dif	No	Demand patch
96	Demand patch	L5406.dif	No	Demand patch

File Number	Description of File	Filename	Climate Change Adjusted	Comments
97	Demand patch	L5606.dif	No	Demand patch
98	Demand patch	L5706.dif	No	Demand patch
99	Demand patch	bri06.dif	No	Demand patch
100	Dummy File	dummy.flo	No	Dummy file - OML/d

B.3.3 Bremer

Table 7.11 Summary of Streamflow Data Used in the Bremer Model

File Number	Description of File	Filename	Climate Change Adjusted	Comments
1	Sub-catchment B1	B1.DM3	Yes	
2	Sub-catchment B2	B2.DM3	Yes	
3	Sub-catchment B3	B3.DM3	Yes	
4	Sub-catchment B4	B4.d11	Yes	
5	Sub-catchment B5	B5.d11	Yes	
6	Sub-catchment B6	B6.d11	Yes	
7	Sub-catchment B7	B7.d11	Yes	
8	Sub-catchment B8	B8.d11	Yes	
9	Sub-catchment B9	B9.d11	Yes	
10	Sub-catchment B10	B10.d11	Yes	
11	Sub-catchment B11	B11.d11	Yes	
12	Sub-catchment B12	B12.d11	Yes	
13	Sub-catchment B13	B13.d11	Yes	
14	Sub-catchment B14	B14.d11	Yes	
15	Sub-catchment B15	B15.d11	Yes	
16	Sub-catchment B16	B16.d11	Yes	
17	Sub-catchment B17	B17.d11	Yes	
18	Sub-catchment B18	B18_05.DMH	Yes	
19	Sub-catchment B19	B19_05.DMH	Yes	
20	Sub-catchment B20	B20_05.DMH	Yes	
21	Sub-catchment B21	B21_05.DMH	Yes	
22	Sub-catchment B22	B22_05.DMH	Yes	
23	Sub-catchment B23	B23_05.DMH	Yes	
24	Sub-catchment B24	B24_05.DMH	Yes	
25	Sub-catchment B25	B25_05.DMH	Yes	
26	Sub-catchment B26	B26_05.DMH	Yes	
27	Sub-catchment B27	B27_05.DMH	Yes	
28	Sub-catchment B28	B28_05.DMB	Yes	
29	Sub-catchment B29	B29_05.DMB	Yes	
30	Sub-catchment B30	B30_05.DMB	Yes	
31	Sub-catchment B31	B31_05.DMB	Yes	
32	Sub-catchment B32	B32_05.DMB	Yes	
33	Sub-catchment B33	b33_05.flw	Yes	
34	Sub-catchment B34	b34_05.flw	Yes	
35	Sub-catchment B35	b35_05.flw	Yes	
36	Sub-catchment B36	B36_05.DMA	Yes	
37	Sub-catchment B37	B37_05.DMA	Yes	
38	Sub-catchment B38	b38_05.flw	Yes	
39	Combination of Flow Files	Rch_2627.PP2	Post processed	Addition of rainfall files b4 + b5 + ... + b17
40	Lagged Flow File	LAG_6M.PP2	Post processed	Rch_2627.ppt' lagged by 183 days
41	Dummy File	Dummy.Flo	No	Dummy file - OML/d

B.3.4 Stanley, Central Brisbane and Lower Brisbane

Table 7.12 Summary of Streamflow Data Used in the Stanley, Central Brisbane and Lower Brisbane Model

File Number	Description of File	Filename	Climate Change Adjusted	Comments
1	Sub-catchment CB1	CB1.s00	Yes	
2	Sub-catchment CB2	CB2.s00	Yes	
3	Sub-catchment CB3	CB3.s00	Yes	
4	Sub-catchment CB4	CB4.s00	Yes	
5	Sub-catchment CB5	CB5.s00	Yes	
6	Sub-catchment CB6	CB6.s00	Yes	
7	Sub-catchment CB7	CB7.s00	Yes	
8	Sub-catchment CB8	CB8.s00	Yes	
9	Sub-catchment CB9	CB9.s00	Yes	
10	Sub-catchment CB10	CB10.s00	Yes	
11	Sub-catchment CB11	CB11.s00	Yes	
12	Sub-catchment CB12	CB12.s00	Yes	
13	Sub-catchment CB13	CB13.s00	Yes	
14	Sub-catchment S1	S1.s00	Yes	
15	Sub-catchment S2	S2.s00	Yes	
16	Sub-catchment S3	S3.s00	Yes	
17	Sub-catchment S4	S4.s00	Yes	
18	Sub-catchment S5	S5.s00	Yes	
19	Sub-catchment S6	S6.s00	Yes	
20	Sub-catchment S7	S7.s00	Yes	
21	Sub-catchment S8	S8.s00	Yes	
22	Sub-catchment S9	S9.s00	Yes	
23	Sub-catchment S10	S10.s00	Yes	
24	Sub-catchment S11	S11.s00	Yes	
25	Sub-catchment S12	S12.s00	Yes	
26	Sub-catchment S13	S13.s00	Yes	
27	Sub-catchment S14	S14.s00	Yes	
28	Sub-catchment S15	S15.s00	Yes	
29	Sub-catchment S16	S16.s00	Yes	
30	Sub-catchment S17	S17.s00	Yes	
31	Sub-catchment S18	S18.s00	Yes	
32	Sub-catchment S19	S19.s00	Yes	
33	Sub-catchment S20	S20.s00	Yes	
34	Sub-catchment S21	S21.s00	Yes	
35	Sub-catchment LB1	LB1.s00	Yes	
36	Sub-catchment LB2	LB2.s00	Yes	
37	Sub-catchment LB3	LB3.s00	Yes	
38	Sub-catchment LB4	LB4.s00	Yes	
39	Sub-catchment LB5	LB5.s00	Yes	
40	Sub-catchment LB6	LB6.s00	Yes	
41	Sub-catchment LB7	LB7.s00	Yes	
42	Sub-catchment LB8	lm_1006.dm2	Yes	
43	Sub-catchment LB9	LB9.s00	Yes	
44	Sub-catchment LB10	LB10_05.flw	Yes	
45	Sub-catchment LB11	LB11_05.flw	Yes	
46	Sub-catchment LB12	LB12_05.flw	Yes	
47	Sub-catchment LB13	LB13_05.flw	Yes	
48	Sub-catchment LB14	LB14_05.flw	Yes	
49	Sub-catchment LB15	LB15_05.flw	Yes	

File Number	Description of File	Filename	Climate Change Adjusted	Comments
50	Sub-catchment LB16	Lb16.DM2	Yes	
51	Sub-catchment LB17a	LB17a_06.flw	Yes	
52	Sub-catchment LB18	LB18_05.flw	Yes	
53	Sub-catchment LB19	LB19_05.flw	Yes	
54	Sub-catchment LB20	LB20.DM7	Yes	
55	Sub-catchment LB21	LB21_05.flw	Yes	
56	Sub-catchment LB22	LB22_05.flw	Yes	
57	Sub-catchment LB23	LB23.flw	Yes	
58	Sub-catchment LB24	LB24_05.flw	Yes	
59	Sub-catchment LB25	LB25_05.flw	Yes	
60	Sub-catchment LB26	LB26_05.flw	Yes	
61	Sub-catchment LB27	LB27_05.flw	Yes	
62	Sub-catchment LB28	LB28_05.flw	Yes	
63	Sub-catchment LB29	LB29_05.flw	Yes	
64	Sub-catchment LB30	LB30_05.flw	Yes	
65	Sub-catchment LB31	LB31_05.flw	Yes	
66	Sub-catchment LB32	LB32_05.flw	Yes	
67	Sub-catchment LB33	LB33-06.sm7	Yes	
68	Sub-catchment LB34	LB34-06.sm7	Yes	
69	Sub-catchment LB35	LB35-06.sm7	Yes	
70	Sub-catchment LB36	LB36-06.sm7	Yes	
71	Sub-catchment LB37	LB37-06.sm7	Yes	
72	Sub-catchment LB38	LB38-06.sm7	Yes	
73	Sub-catchment LB39	LB39-06.sm7	Yes	
74	Sub-catchment LB40	LB40-06.sm7	Yes	
75	Sub-catchment LB41	LB41-06.sm7	Yes	
76	Sub-catchment LB42	LB42_05.flw	Yes	
77	Sub-catchment LB43	LB43_05.flw	Yes	
78	Sub-catchment LB44	LB44.DM3	Yes	
79	Sub-catchment LB45	LB45.DM3	Yes	
80	Sub-catchment LB46	LB46.DM3	Yes	
81	Sub-catchment LB47	LB47_05.flw	Yes	
82	Sub-catchment LB48	LB48_05.flw	Yes	
83	Sub-catchment LB49	LB49_05.flw	Yes	
84	Sub-catchment LB50	LB50_05.flw	Yes	
85	Sub-catchment LB51	LB51_05.flw	Yes	
86	Upper Brisbane Inflow	189a-290.01a	No	
87	Lockyer Inflow	157a-544.01b	No	
88	Bremer Inflow	111a-327.01d	No	
89	Wivenhoe Work Around	020f-555.wwa	No	Wivenhoe Work Around
90	Somerset Work Around	020f-089.swa	No	Somerset Work Around
91	Woodford TWS	woodford.dif	No	Woodford TWS
92	Kilcoy TWS	kilcoy.dif	No	Kilcoy TWS
93	Dummy File	bigdummy.flo	No	Dummy file - 10,000ML/d
94	Lake Manchester	lakeman.di2	No	Lake Manchester
95	Sub-catchment LB17B	Lb17b_06.Flw	Yes	
96	Dummy File	dummy.flo	No	Dummy file - 0ML/d

APPENDIX C Climate Change Factors

C.1 Spatial Variation in Rainfall Change Factors (GCM and CCAM)

Table 7.13 Description of Relevant Generation Methods

Generation Method	Gridsize	Description
GCM	Ranging from 100 to 400km	Global circulation models developed by various research institutes around the world
CCAM	~20km	Original dynamically downscaled models using the Conformal-Cubic Atmospheric Model (CCAM) – downscaled to 20km

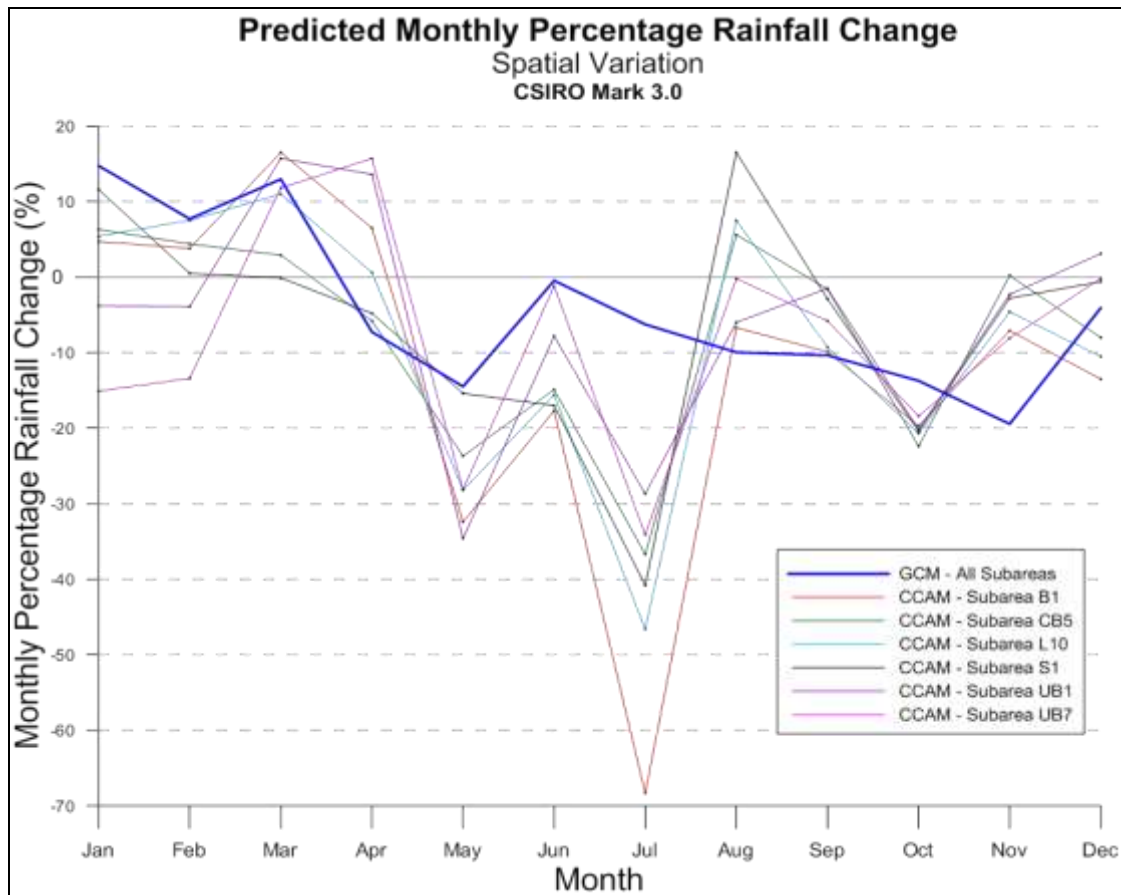


Figure C.1 Spatial variation of projected monthly percentage rainfall change – GCM and CCAM (CSIRO Mark 3.0).

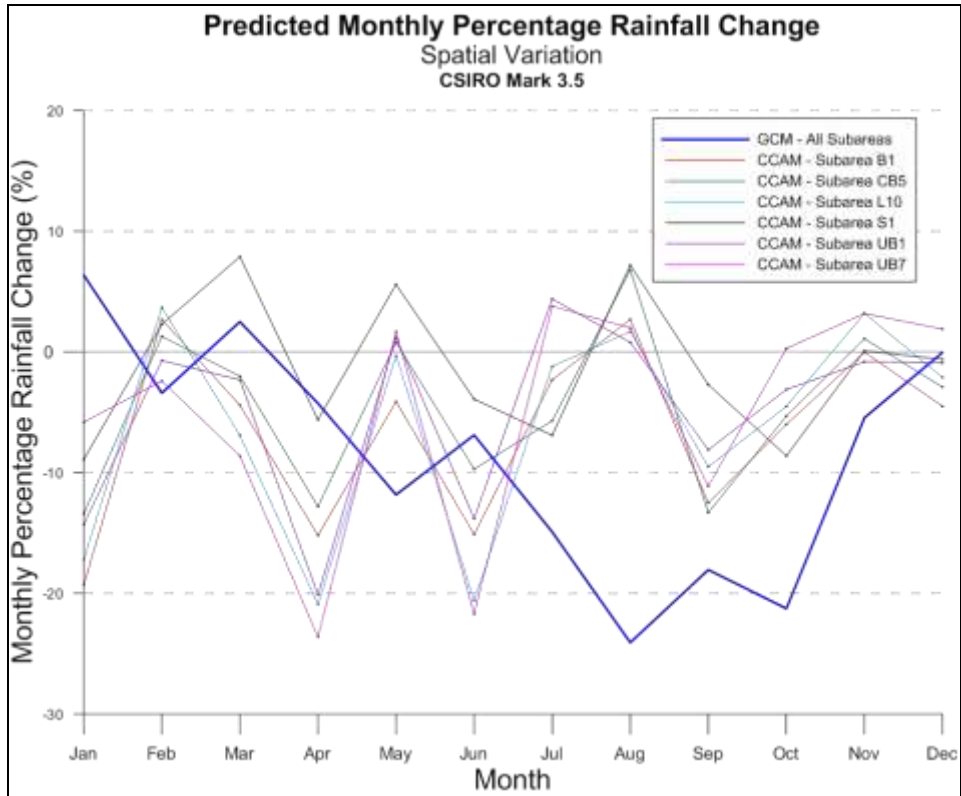


Figure C.2 Spatial variation of projected monthly percentage rainfall change – GCM and CCAM (CSIRO Mark 3.5).

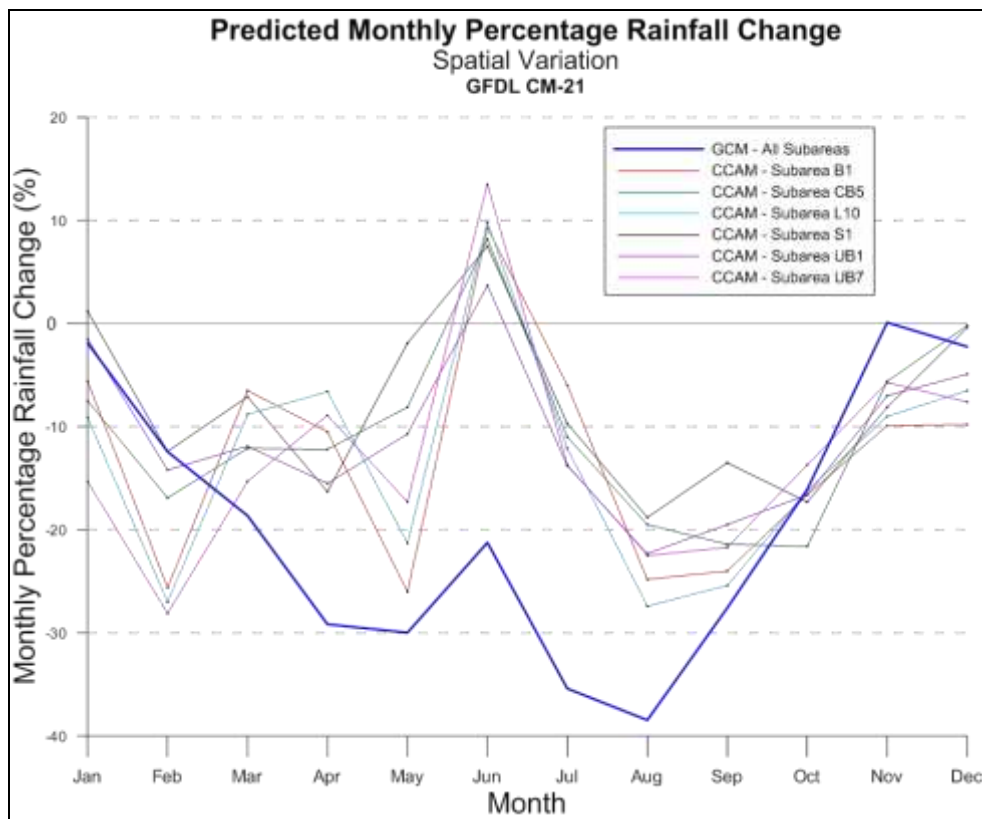


Figure C.3 Spatial variation of projected monthly percentage rainfall change – GCM and CCAM (GFDL CM-21).

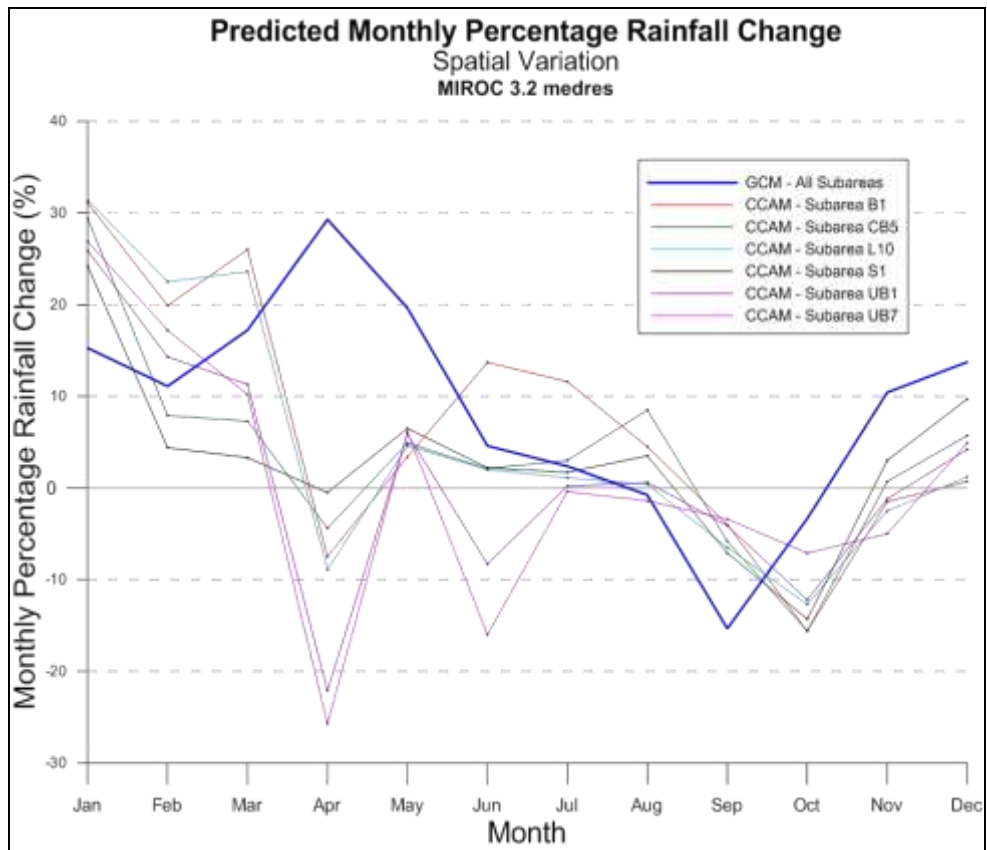


Figure C.4 Spatial variation of projected monthly percentage rainfall change – GCM and CCAM (MIRCO 3.2 medres).

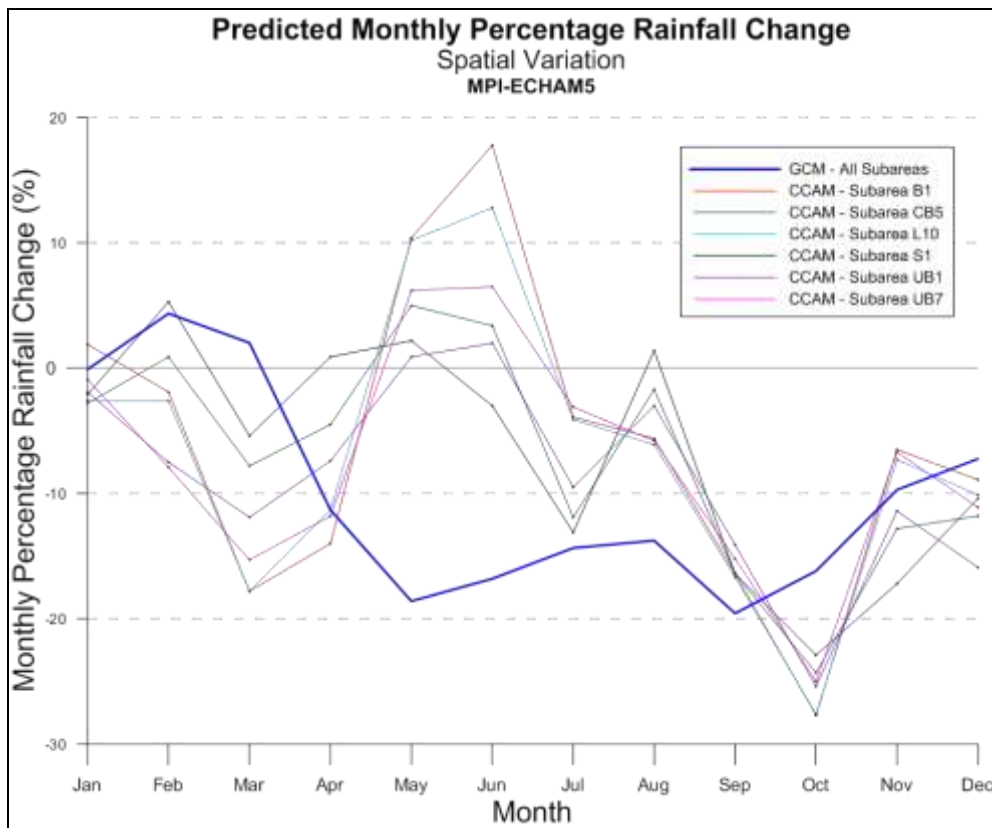


Figure C.5 Spatial variation of projected monthly percentage rainfall change – GCM and CCAM (MPI-ECHAM5).

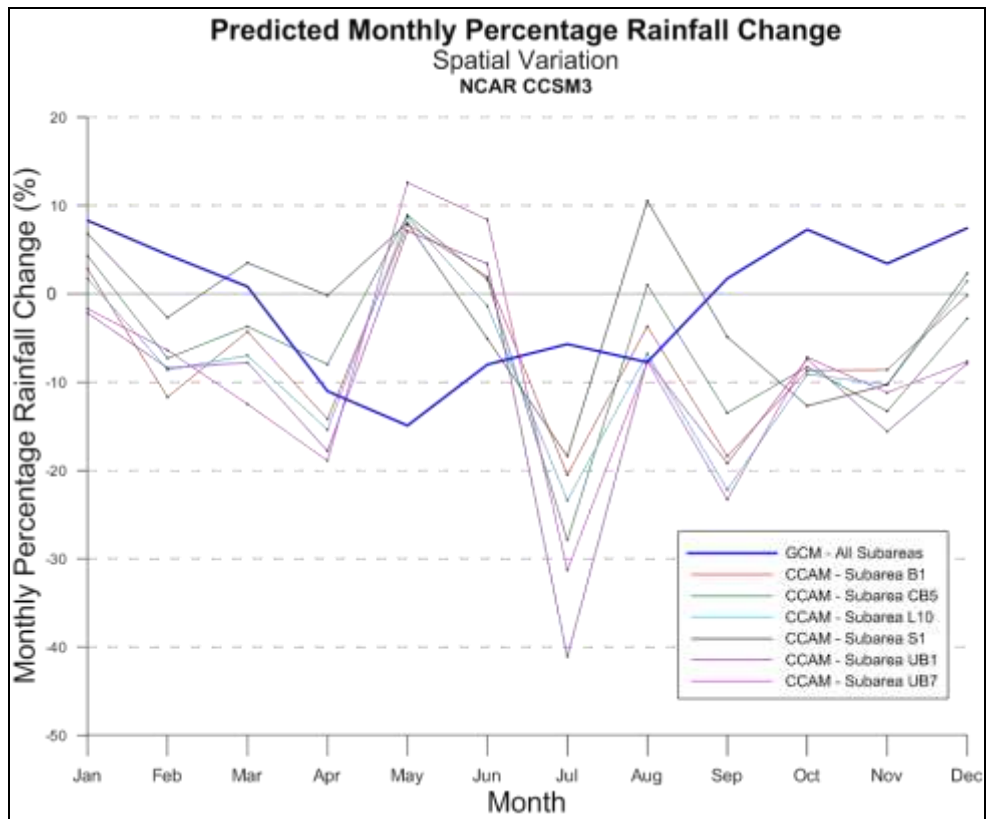


Figure C.6 Spatial variation of projected monthly percentage rainfall change – GCM and CCAM (NCAR CCSM3).

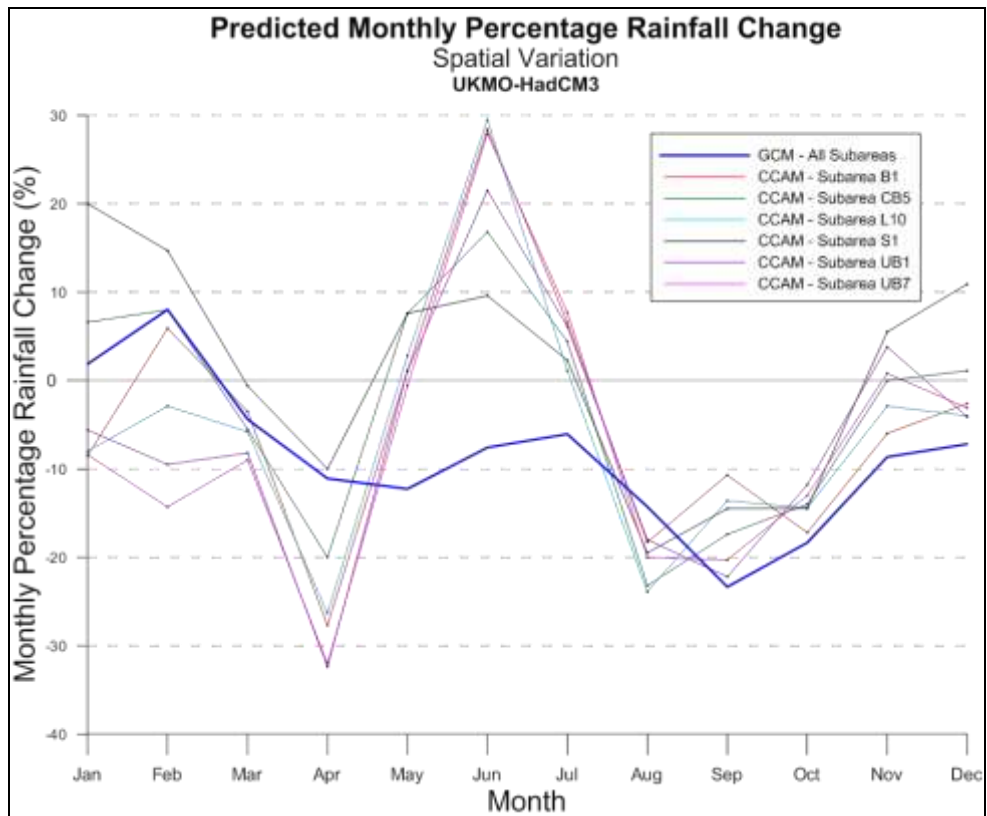


Figure C.7 Spatial variation of projected monthly percentage rainfall change – GCM and CCAM (UKMO-HadCM3).

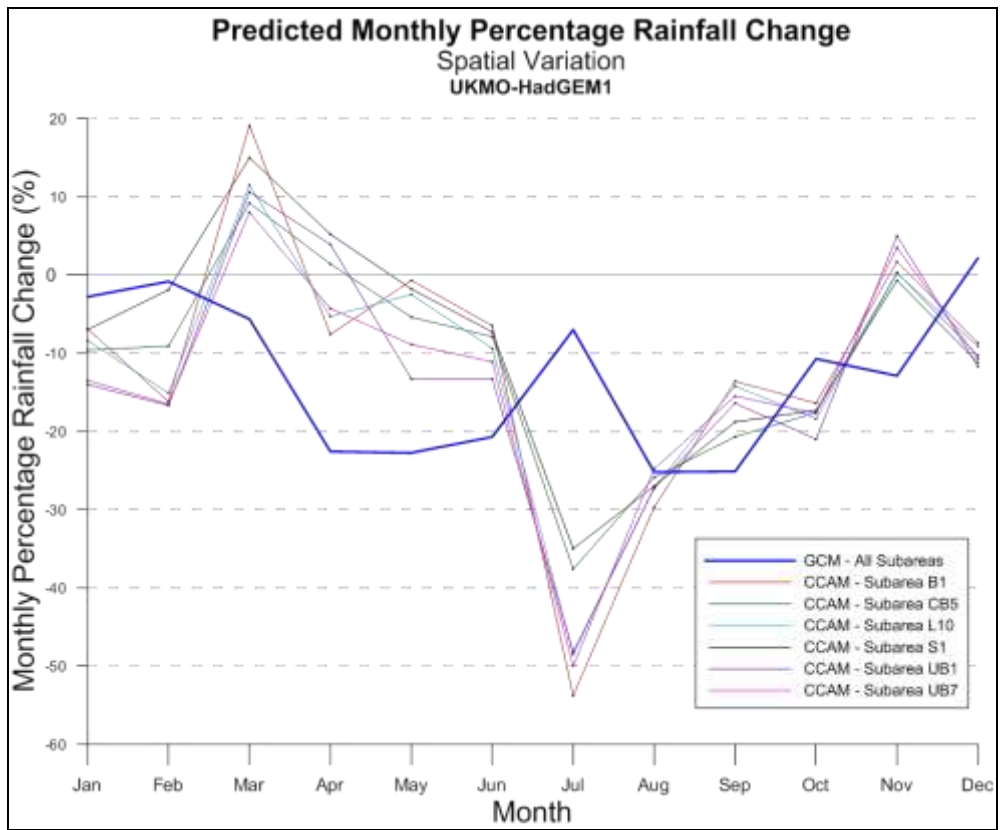


Figure C.8 Spatial variation of projected monthly percentage rainfall change – GCM and CCAM (UKMO-HadGEM1).

C.2 Climate Model Variation in Climate Change Factors (GCM and CCAM)

Table 7.14 Description of Relevant Generation Methods.

Generation Method	Gridsize	Description
GCM	Ranging from 100 to 400km	Global circulation models developed by various research institutes around the world
CCAM	~20km	Original dynamically downscaled models using the Conformal-Cubic Atmospheric Model (CCAM) – downscaled to 20km

C.2.1 Rainfall

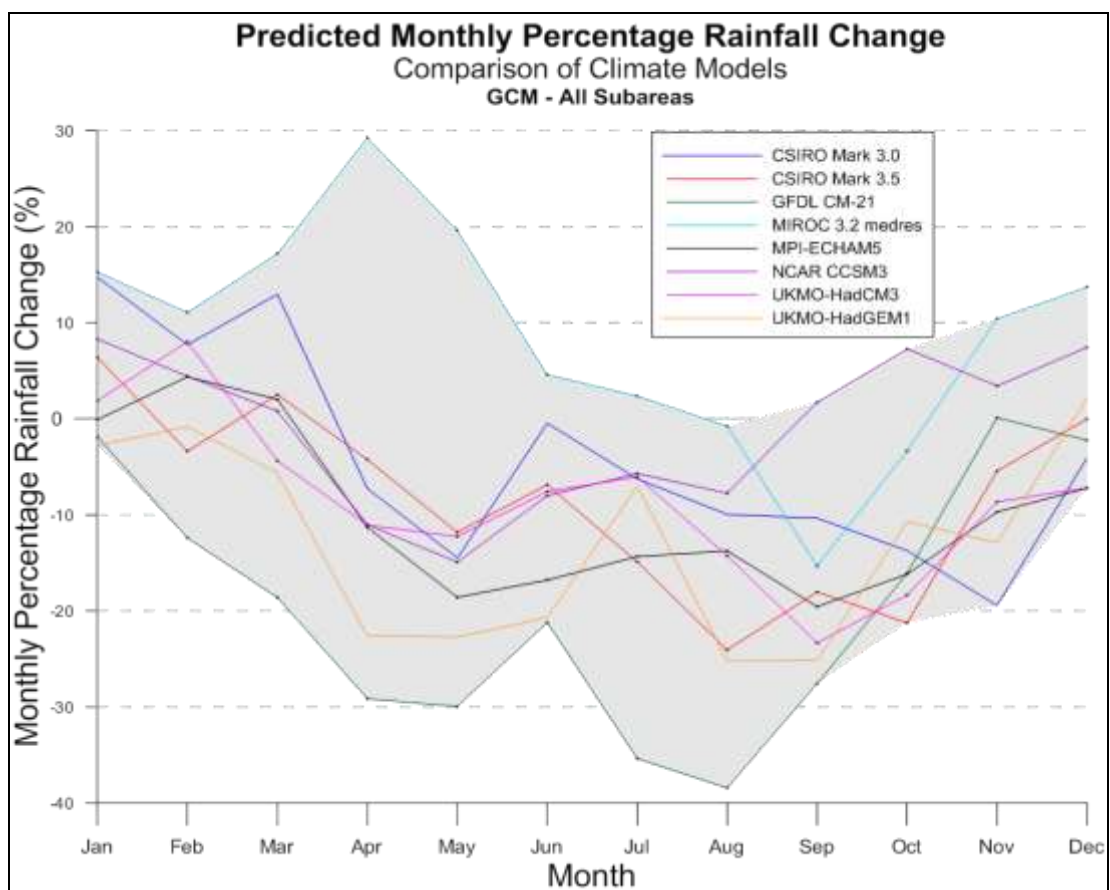


Figure C.9 Climate model variation of projected monthly percentage rainfall change – Whole Catchment – GCM.

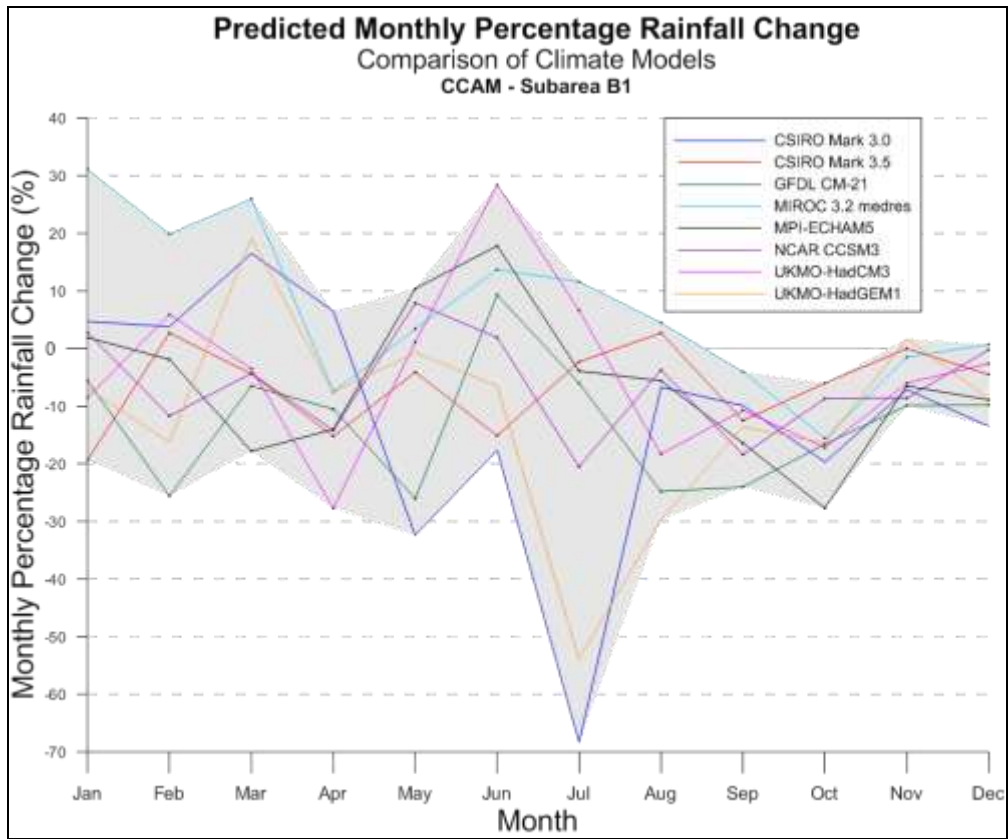


Figure C.10 Climate model variation of projected monthly percentage rainfall change – Subarea B1 – CCAM.

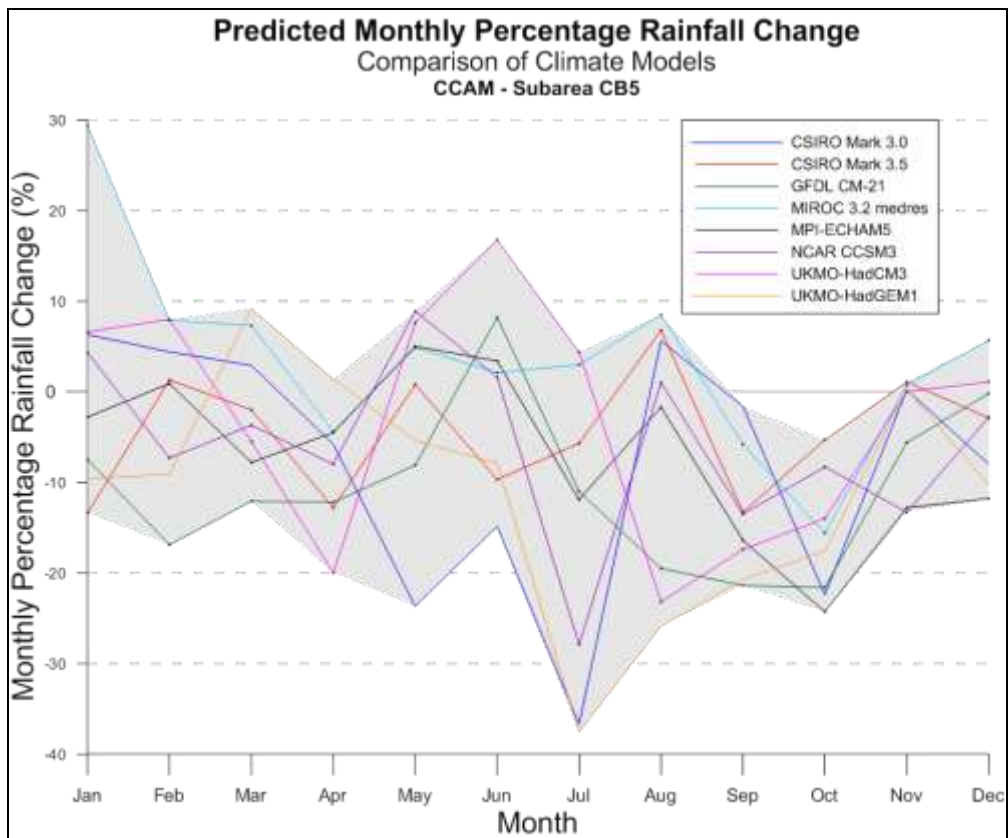


Figure C.11 Climate model variation of projected monthly percentage rainfall change – Subarea CB5 – CCAM.

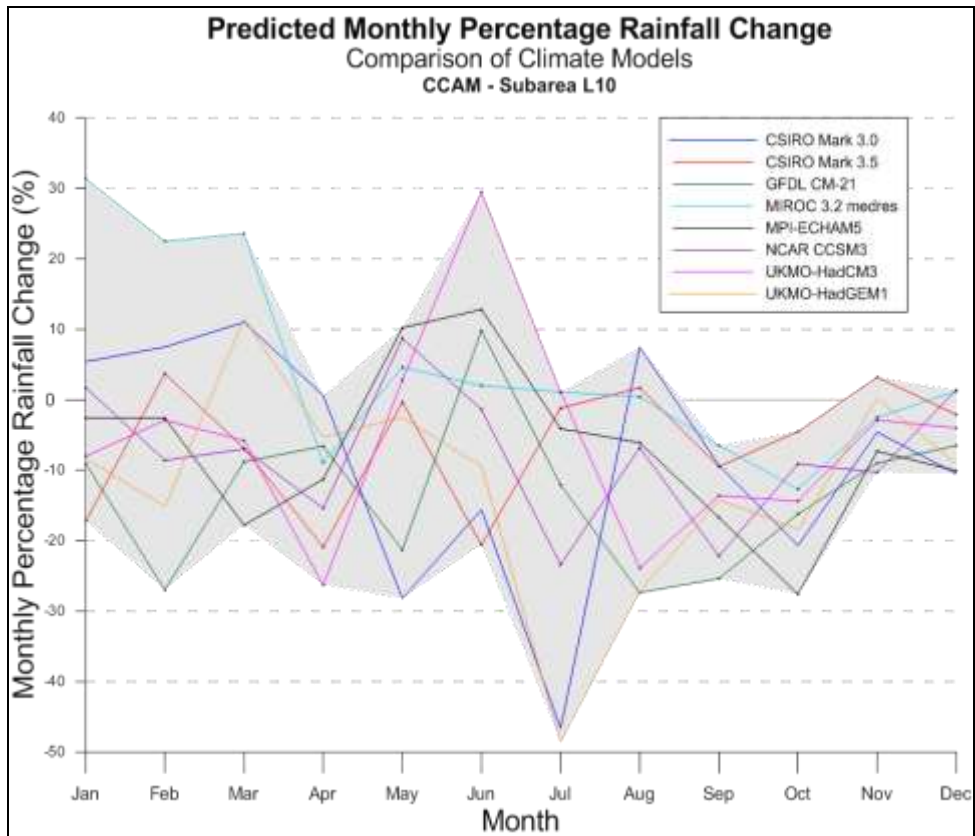


Figure C.12 Climate model variation of projected monthly percentage rainfall change – Subarea L10 – CCAM.

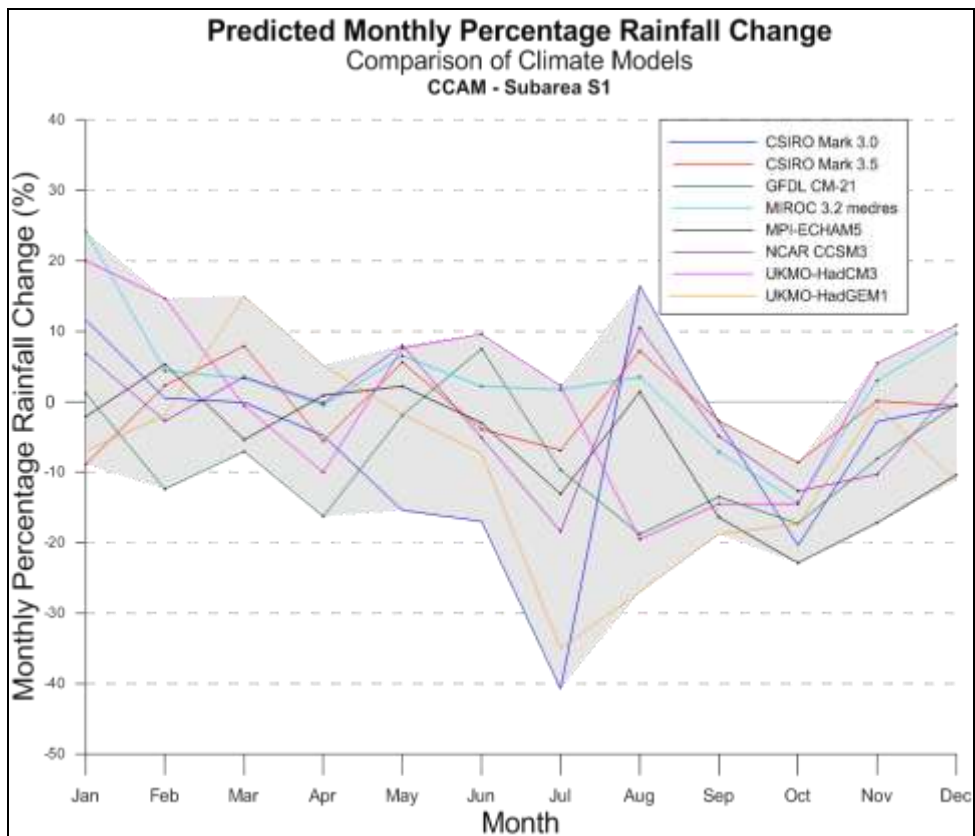


Figure C.13 Climate model variation of projected monthly percentage rainfall change – Subarea S1 – CCAM.

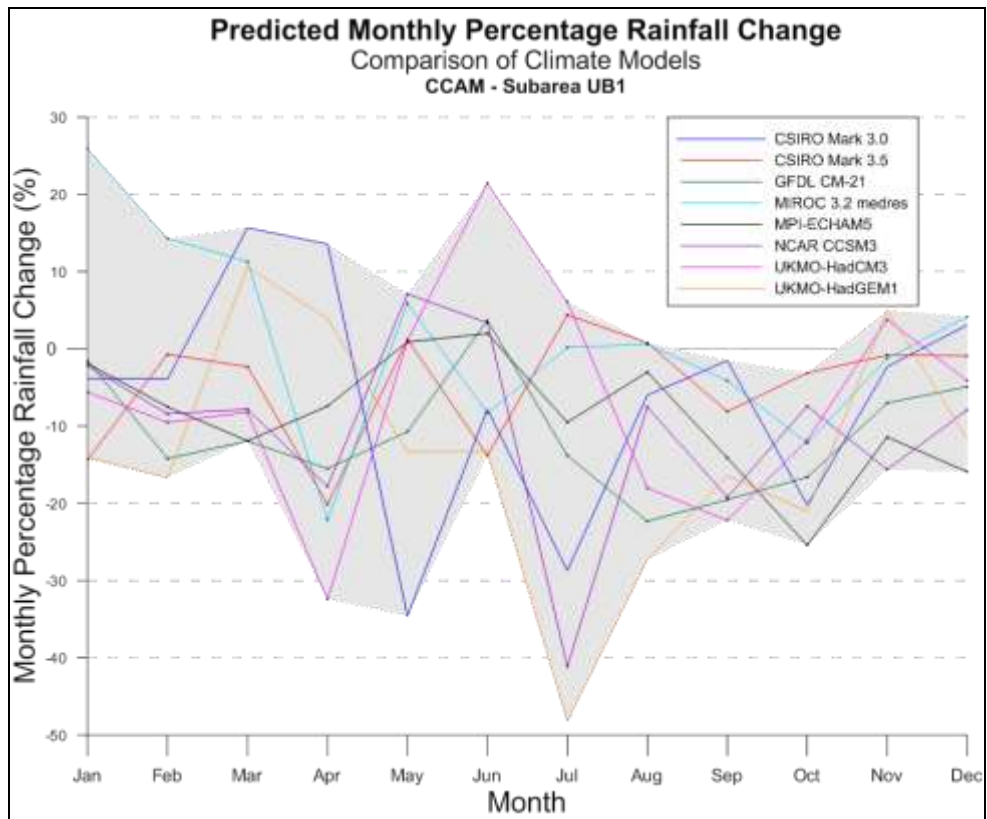


Figure C.14 Climate model variation of projected monthly percentage rainfall change – Subarea UB1 – CCAM.

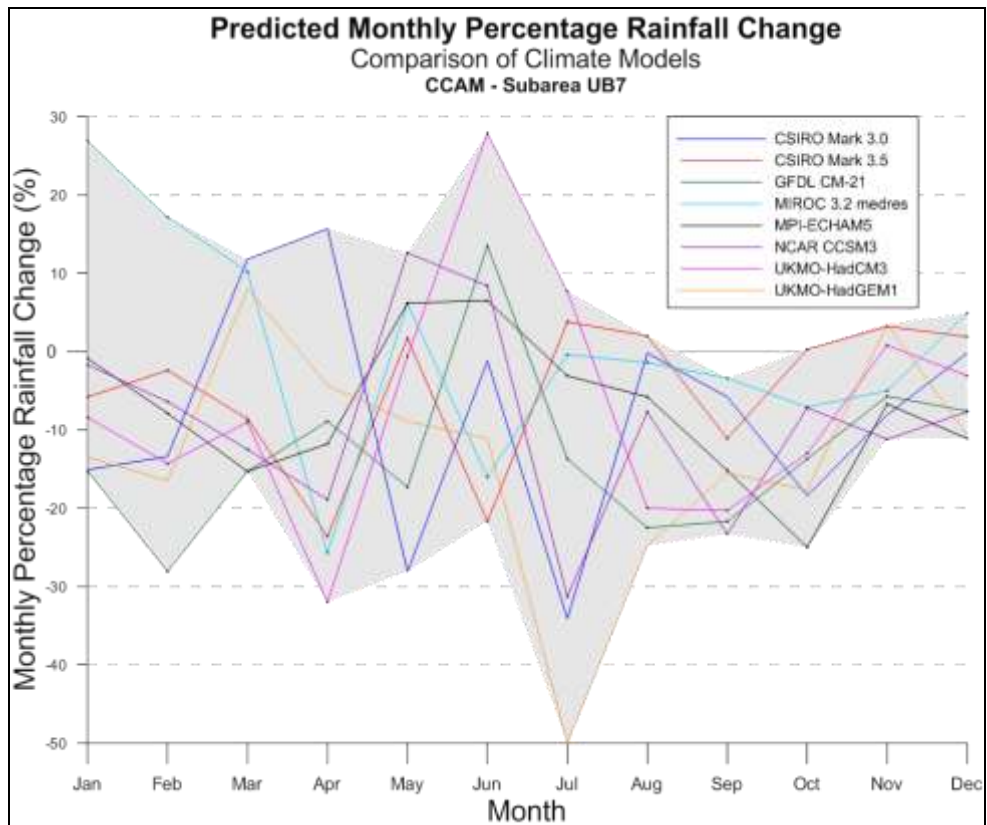


Figure C.15 Climate model variation of projected monthly percentage rainfall change – Subarea UB7 – CCAM.

C.2.2 Evaporation

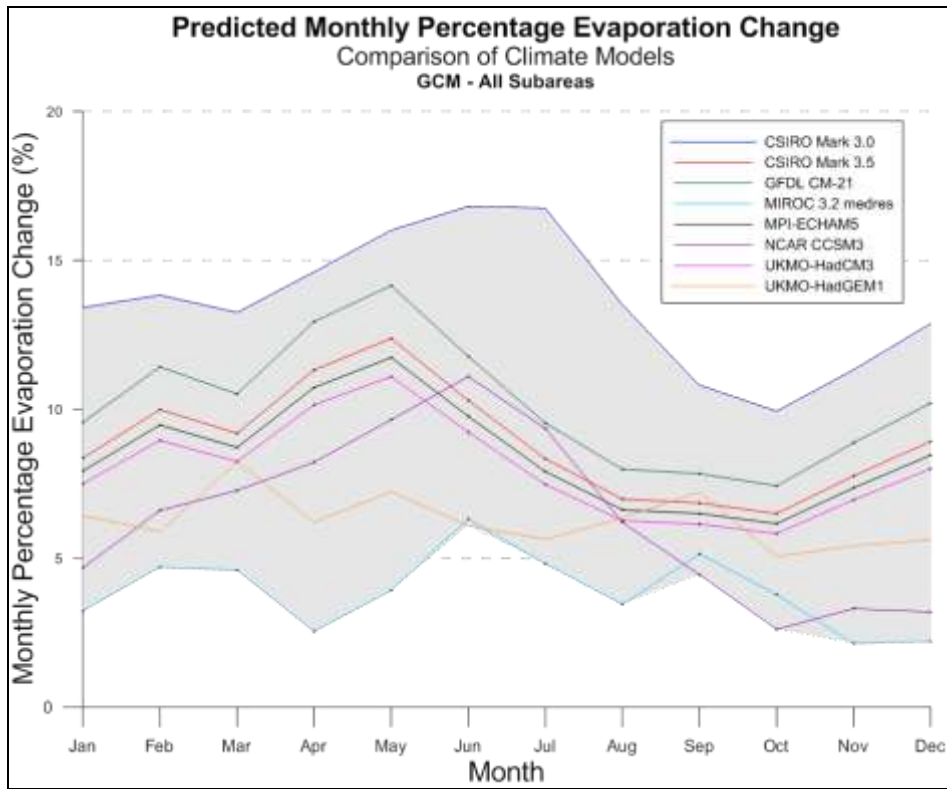


Figure C.16 Climate model variation of projected monthly percentage evaporation change – Whole Catchment – GCM.

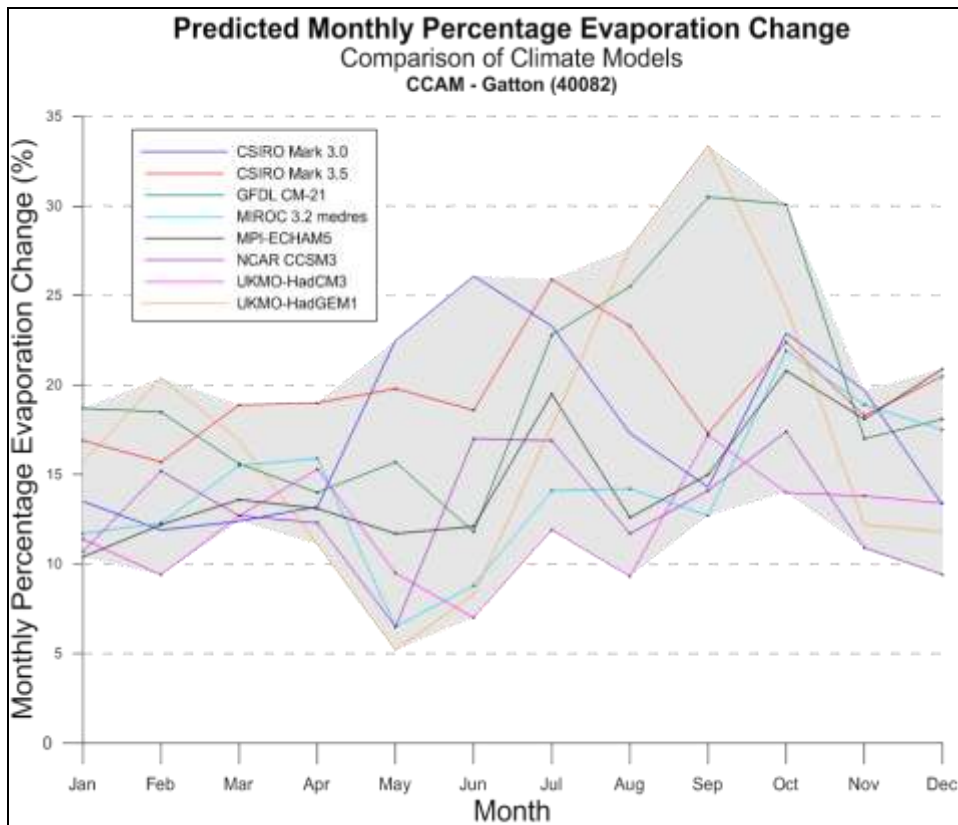


Figure C.17 Climate model variation of projected monthly percentage evaporation change – Gatton (40082) – CCAM.

C.3 Generation Method Variation in Climate Change Factors (GCM, CCAM and CCAM PPE1)

Table 7.15 Description of Relevant Generation Methods.

Generation Method	Gridsize	Description
GCM	Ranging from 100 to 400km	Global circulation models developed by various research institutes around the world
CCAM	~20km	Original dynamically downscaled models using the Conformal-Cubic Atmospheric Model (CCAM) – downscaled to 20km
CCAM PPE1	~ 8km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 8km
CCAM PPE1	~20km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 20km

C.3.1 Rainfall

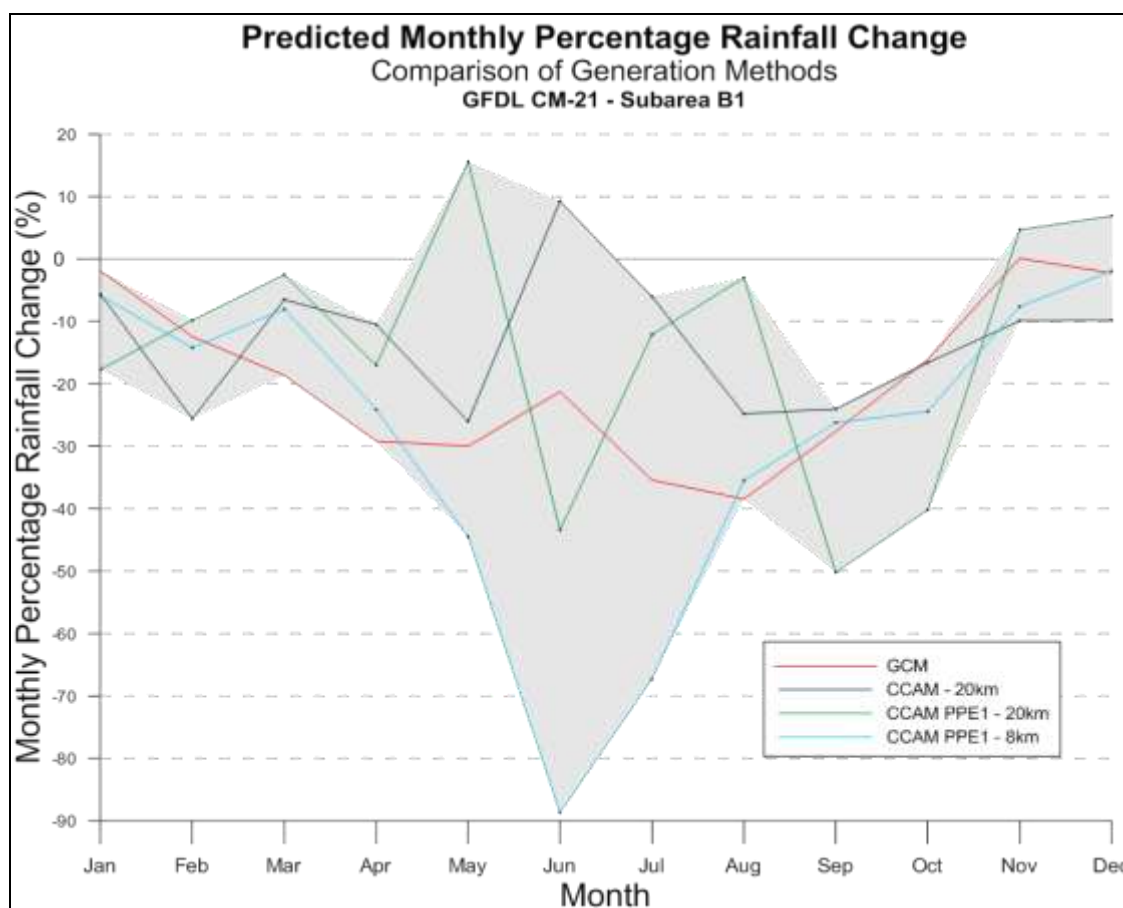


Figure C.18 Generation method variation of projected monthly percentage rainfall change – GFDL CM-21 – Subarea B1.

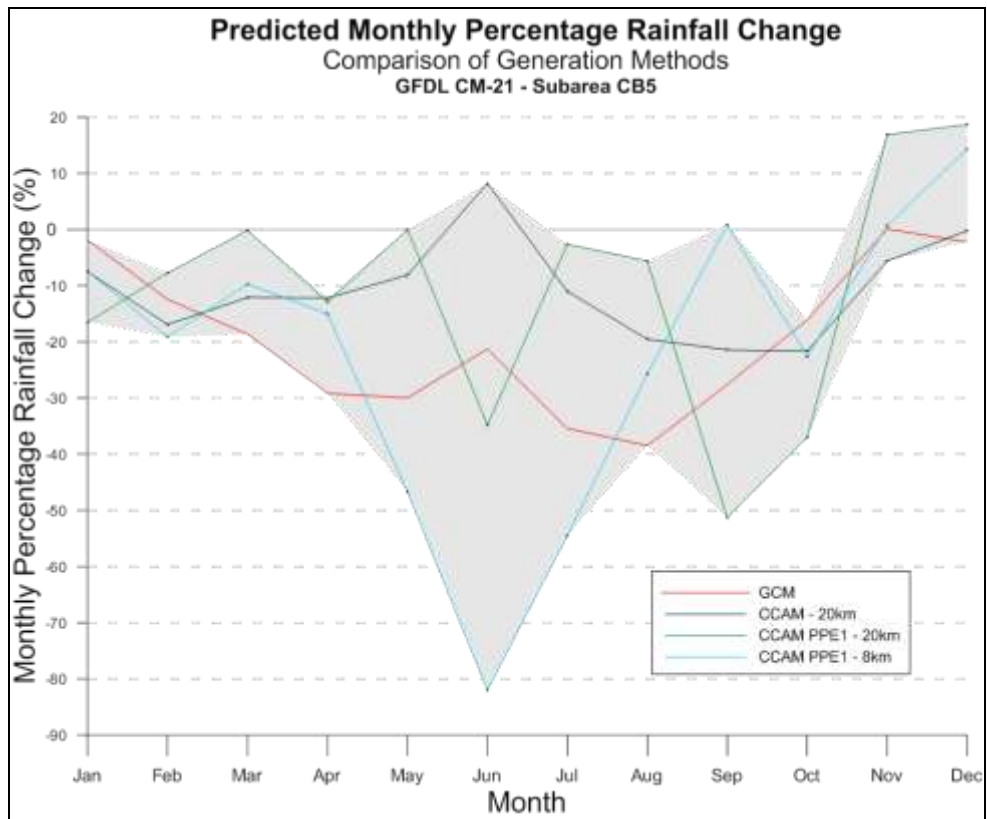


Figure C.19 Generation method variation of projected monthly percentage rainfall change – GFDL CM-21 – Subarea CB5.

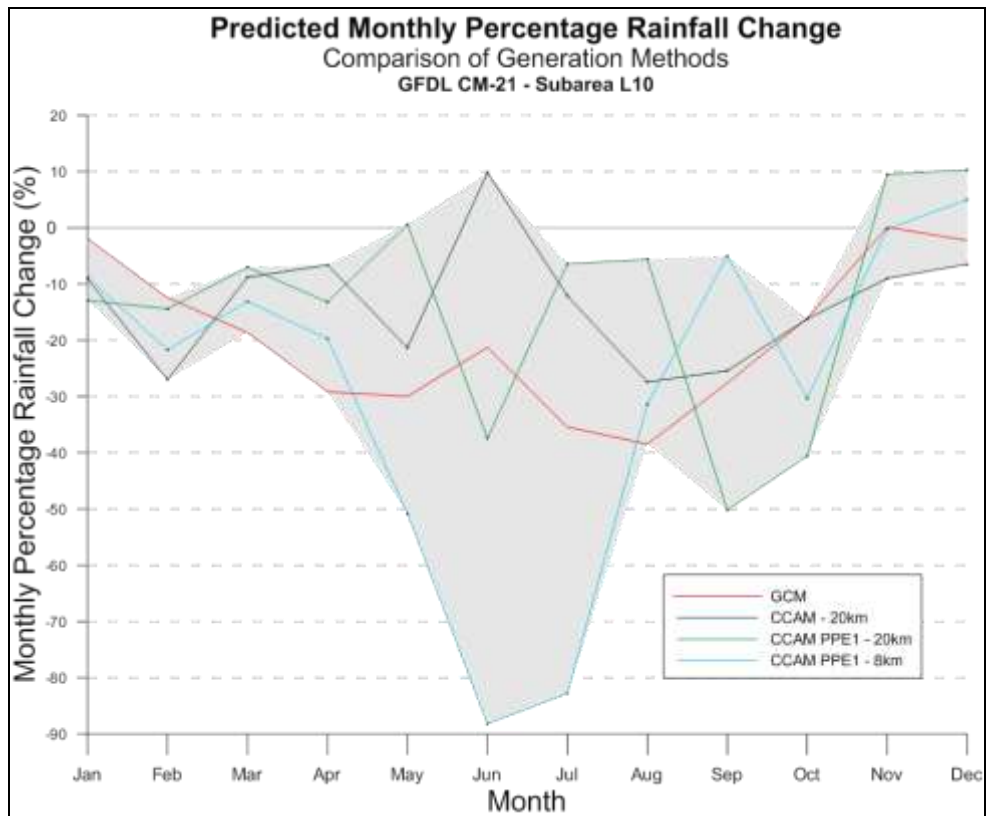


Figure C.20 Generation method variation of projected monthly percentage rainfall change – GFDL CM-21 – Subarea L10.

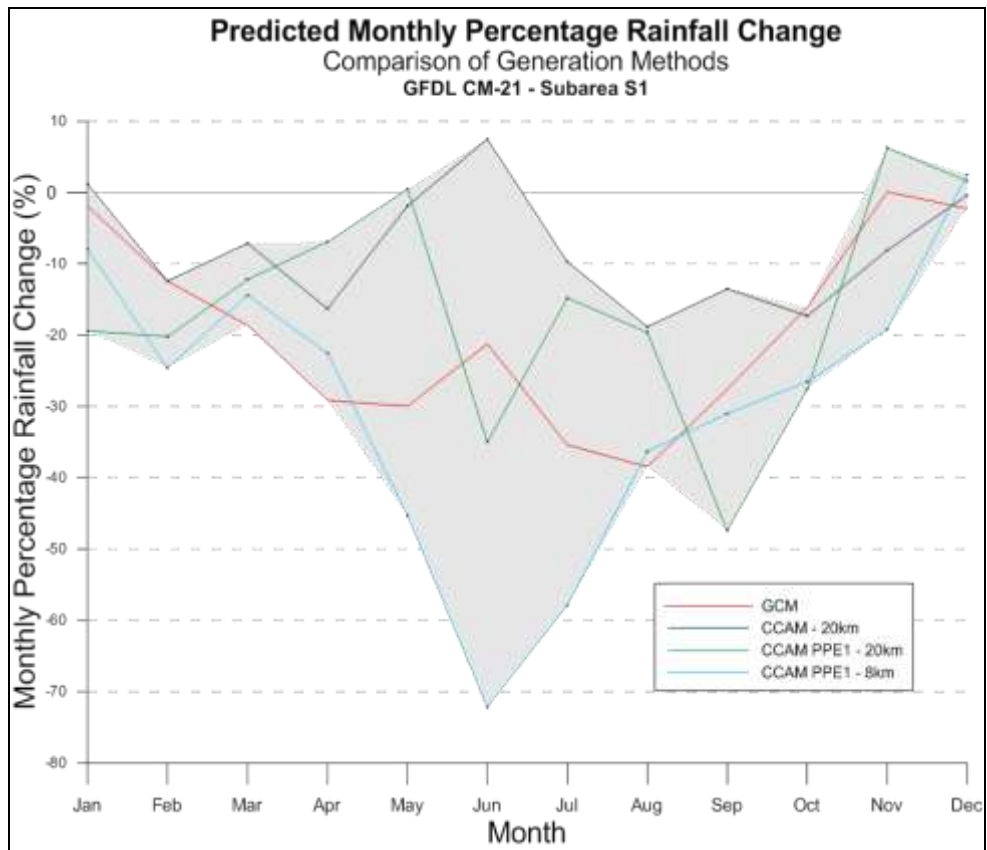


Figure C.21 Generation method variation of projected monthly percentage rainfall change – GFDL CM-21 – Subarea S1.

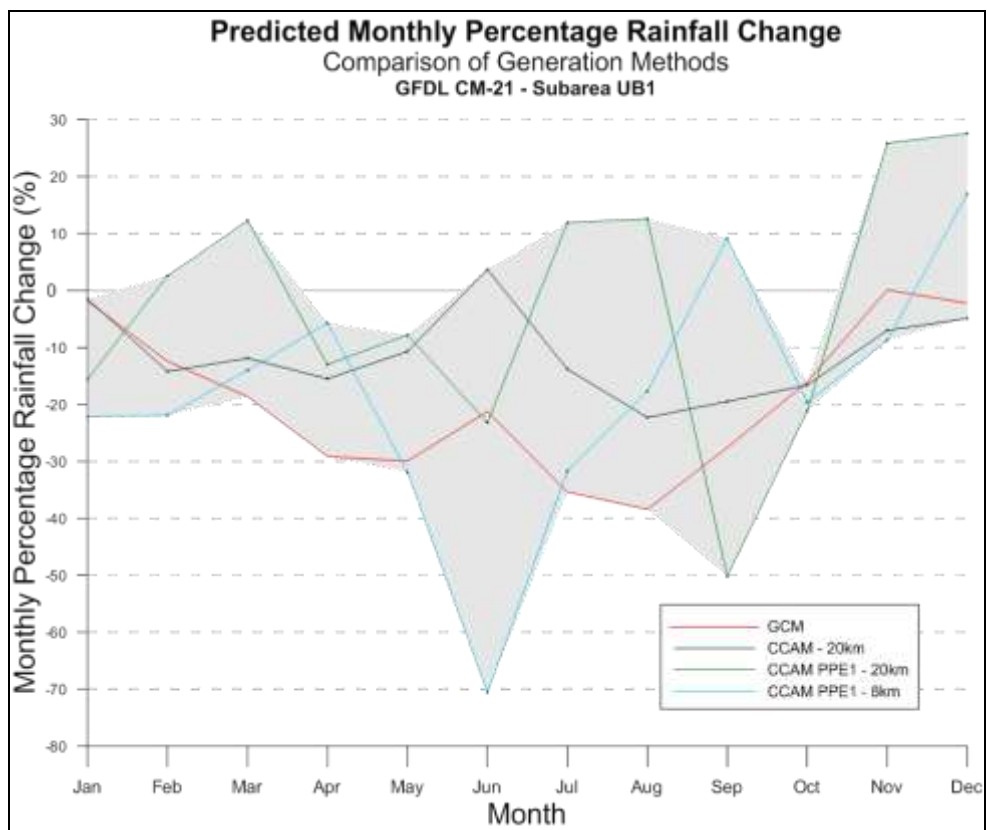


Figure C.22 Generation method variation of projected monthly percentage rainfall change – GFDL CM-21 – Subarea UB1.

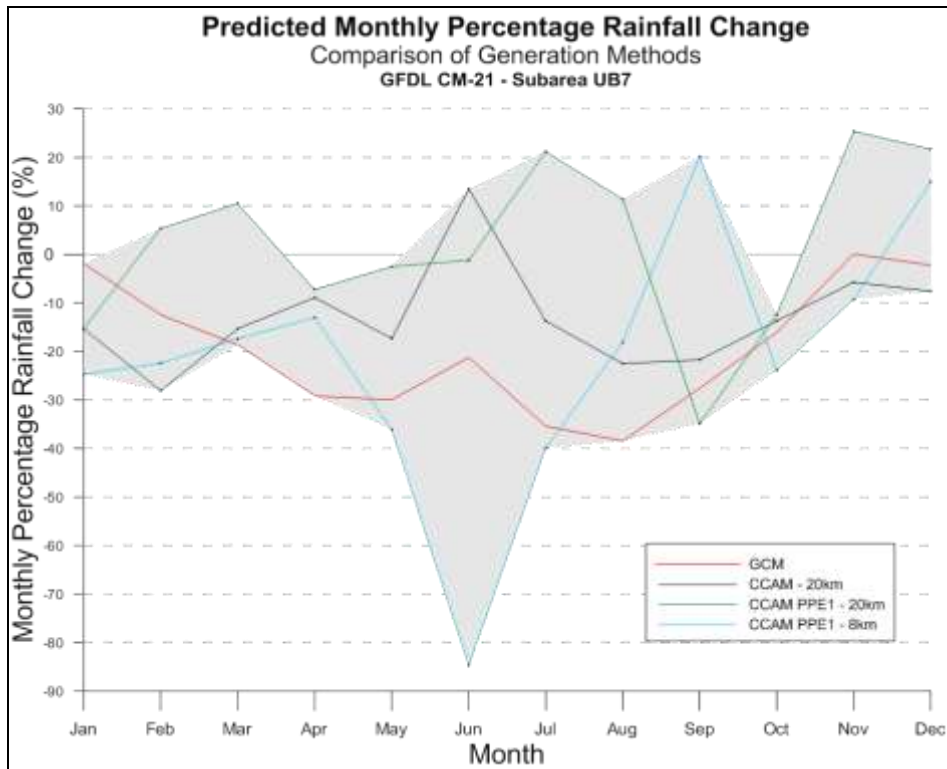


Figure C.23 Generation method variation of projected monthly percentage rainfall change – GFDL CM-21 – Subarea UB7.

C.3.2 Evaporation

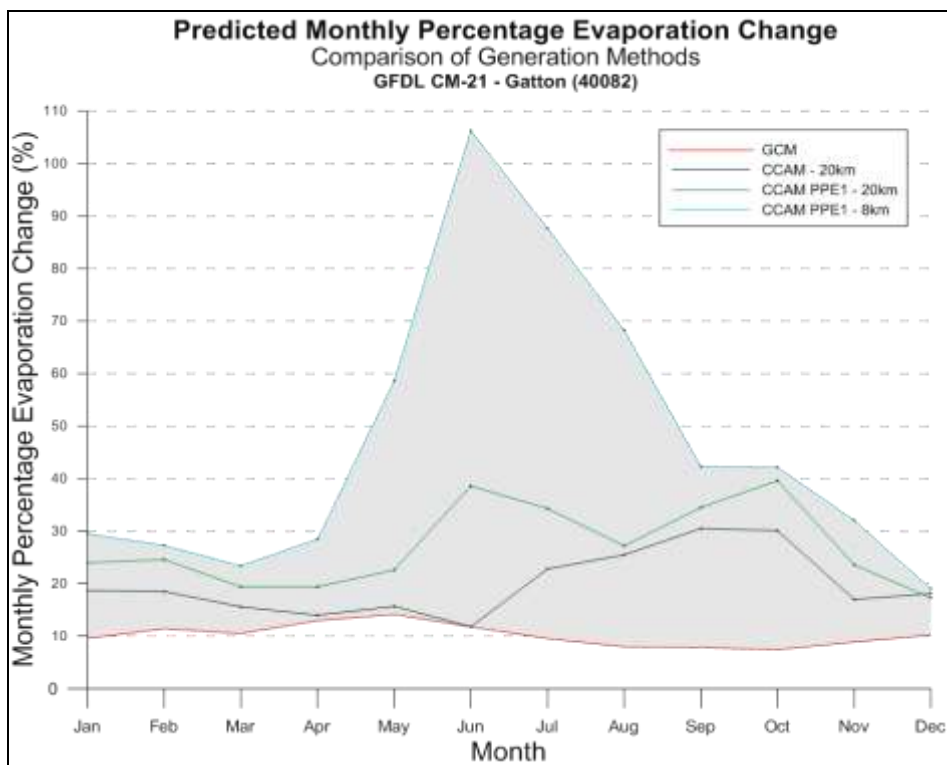


Figure C.24 Generation method variation of projected monthly percentage evaporation change – GFDL CM-21 – Gatton (40082).

C.4 CCAM Generation Method Variation in Climate Change Factors (CCAM PPE1 and CCAM PPE2)

Table 7.16 Description of Relevant Generation Methods

Generation Method	Gridsize	Description
CCAM PPE1	~ 8km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 8km
CCAM PPE1	~20km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 20km
CCAM PPE2	~ 8km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with other changes to uncertainty physical parameters (Perturbed Physics Experiment 2 (PPE2)) – downscaled to 8km
CCAM PPE2	~20km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with other changes to uncertainty physical parameters (Perturbed Physics Experiment 2 (PPE2)) – downscaled to 8km

C.4.1 Rainfall

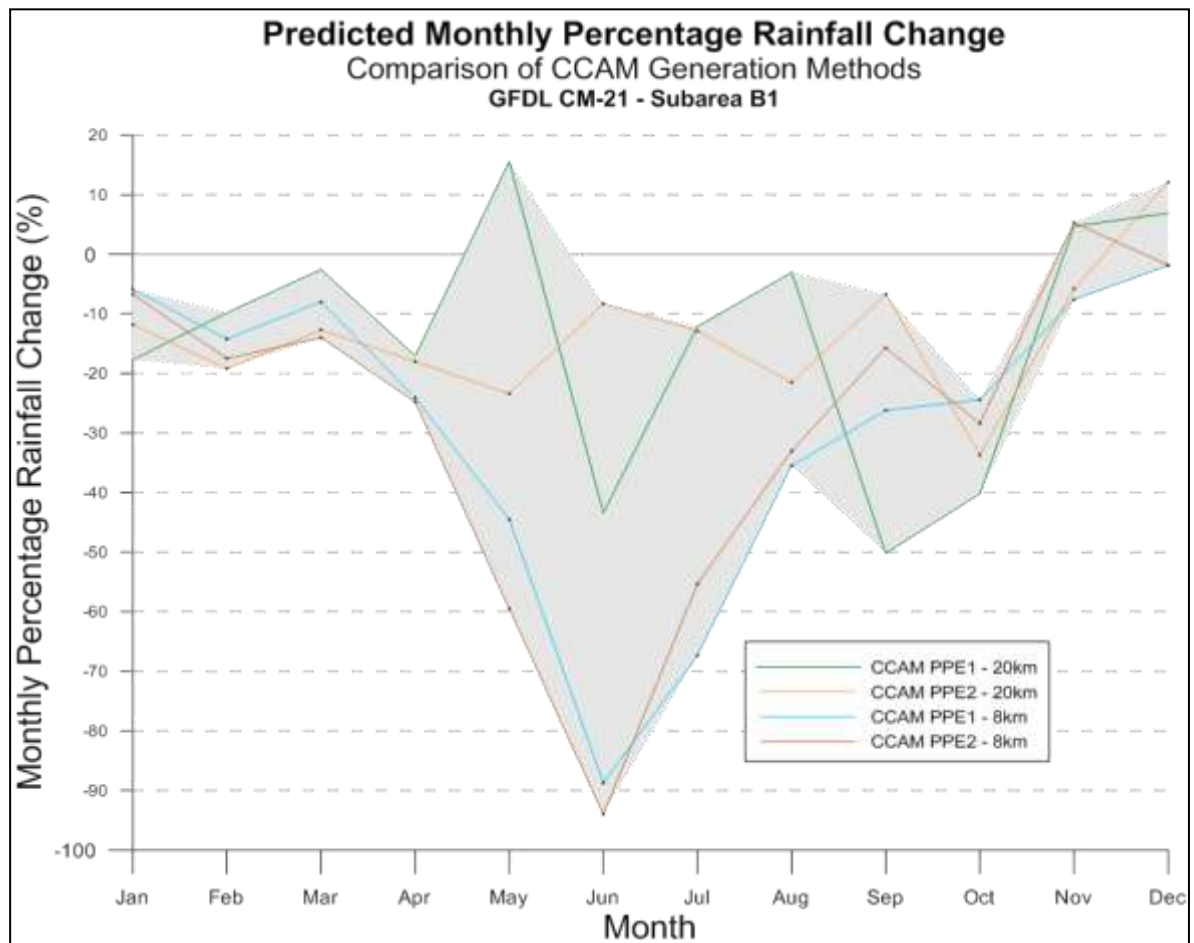


Figure C.25 CCAM generation method variation of projected monthly percentage rainfall change – GFDL CM-21 – Subarea B1.

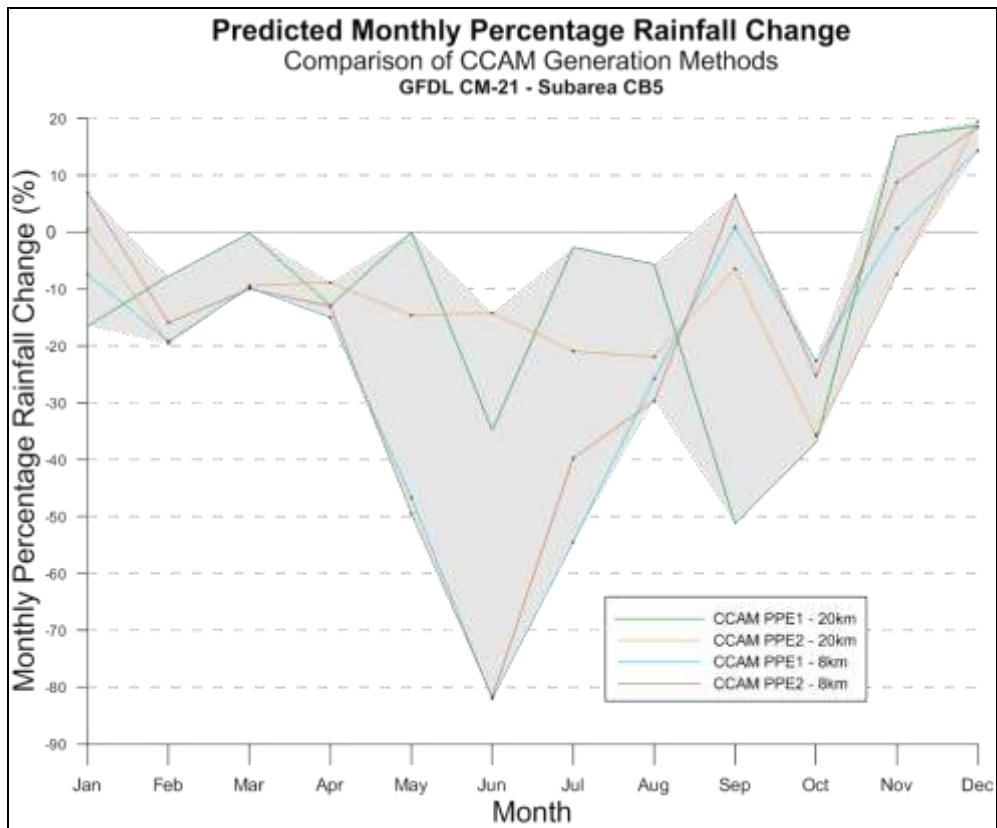


Figure C.26 CCAM generation method variation of projected monthly percentage rainfall change – GFDL CM-21 – Subarea CB5.

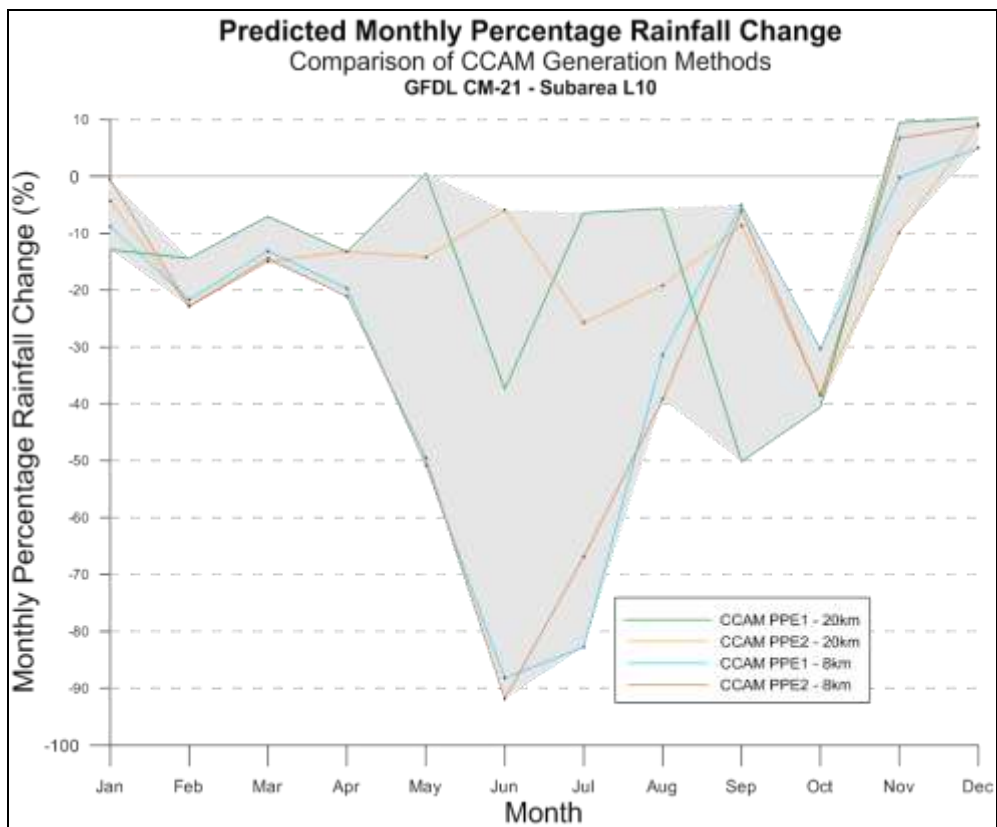


Figure C.27 CCAM generation method variation of projected monthly percentage rainfall change – GFDL CM-21 – Subarea L10.

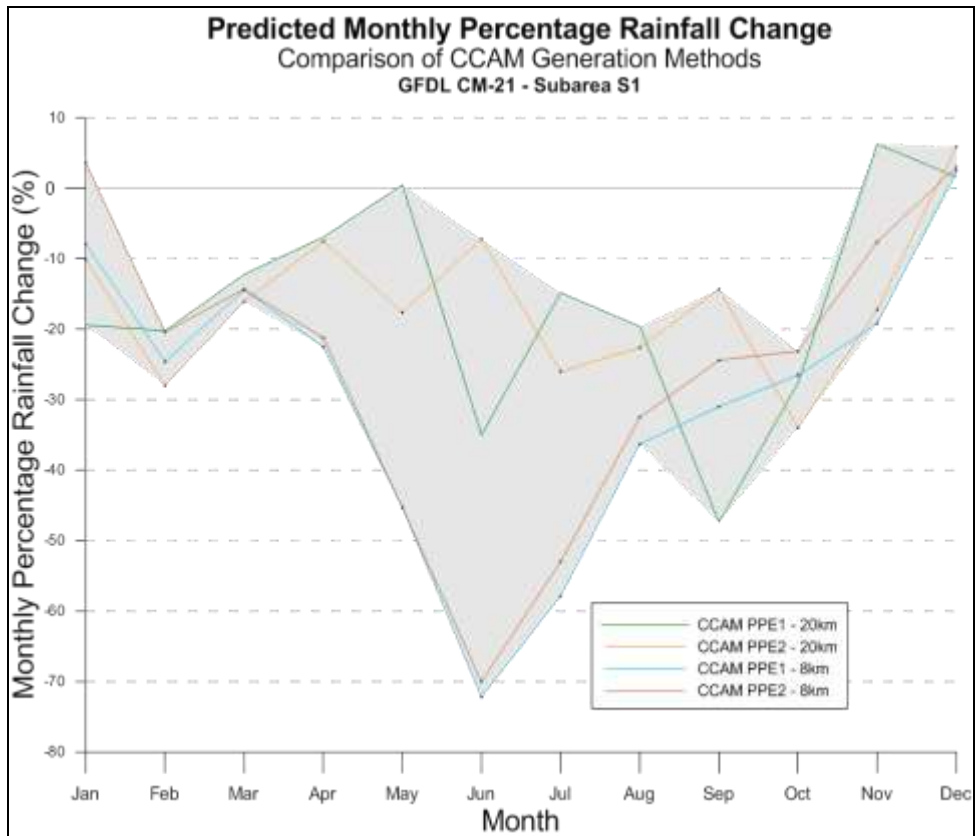


Figure C.28 CCAM generation method variation of projected monthly percentage rainfall change – GFDL CM-21 – Subarea S1.

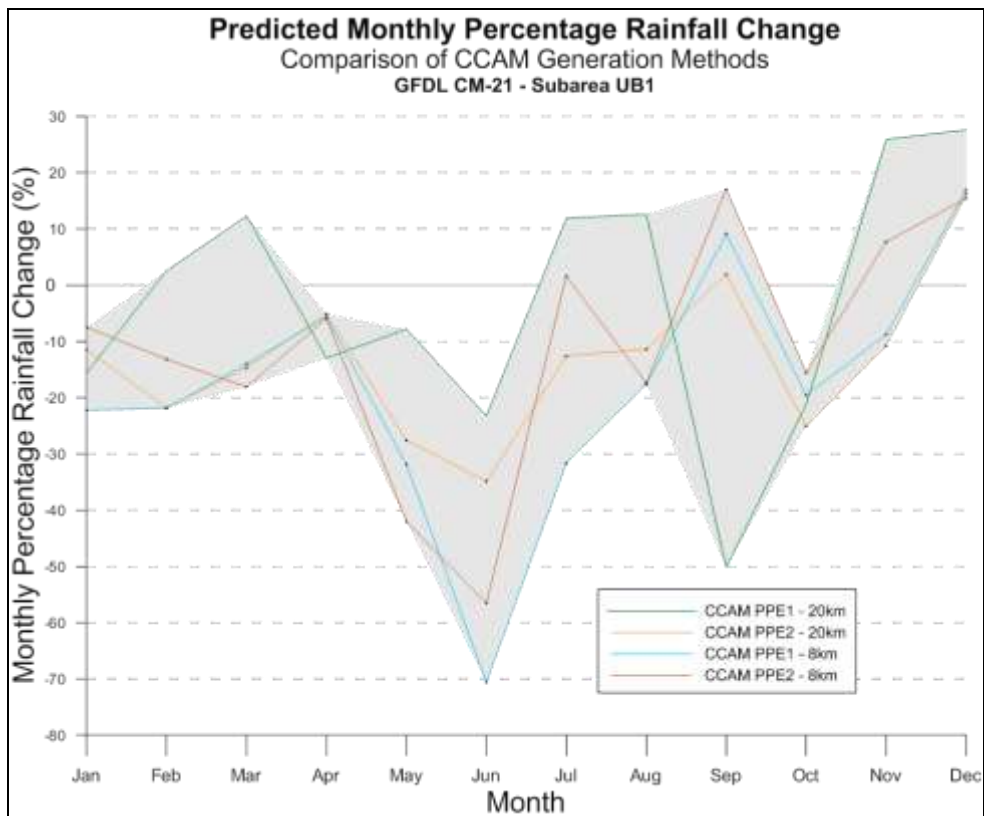


Figure C.29 CCAM generation method variation of projected monthly percentage rainfall change – GFDL CM-21 – Subarea UB1.

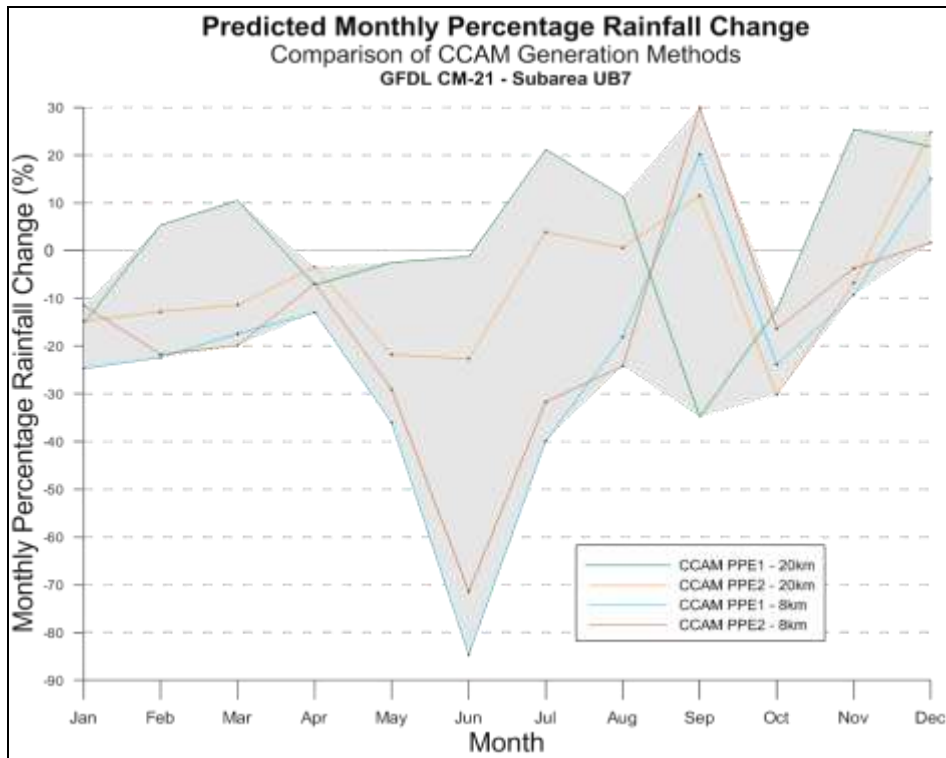


Figure C.30 CCAM generation method variation of projected monthly percentage rainfall change – GFDL CM-21 – Subarea UB7.

C.4.2 Evaporation

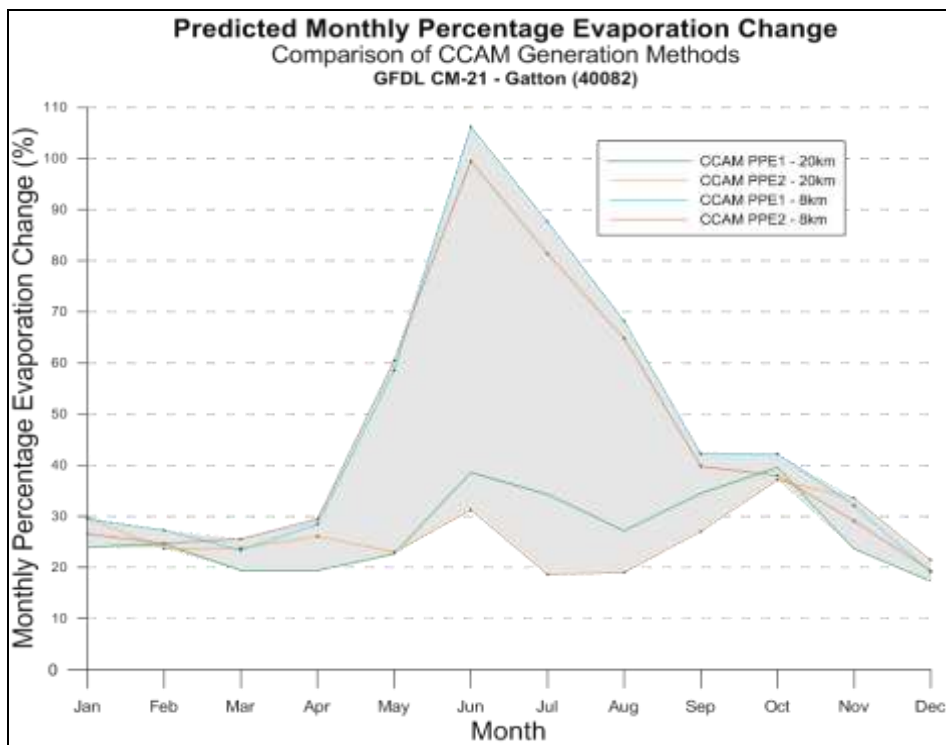


Figure C.31 CCAM generation method variation of projected monthly percentage evaporation change – GFDL CM-21 – Gatton (40082).

APPENDIX D Climate Change Model Input Data – Rainfall

D.1 Global Circulation Model Method

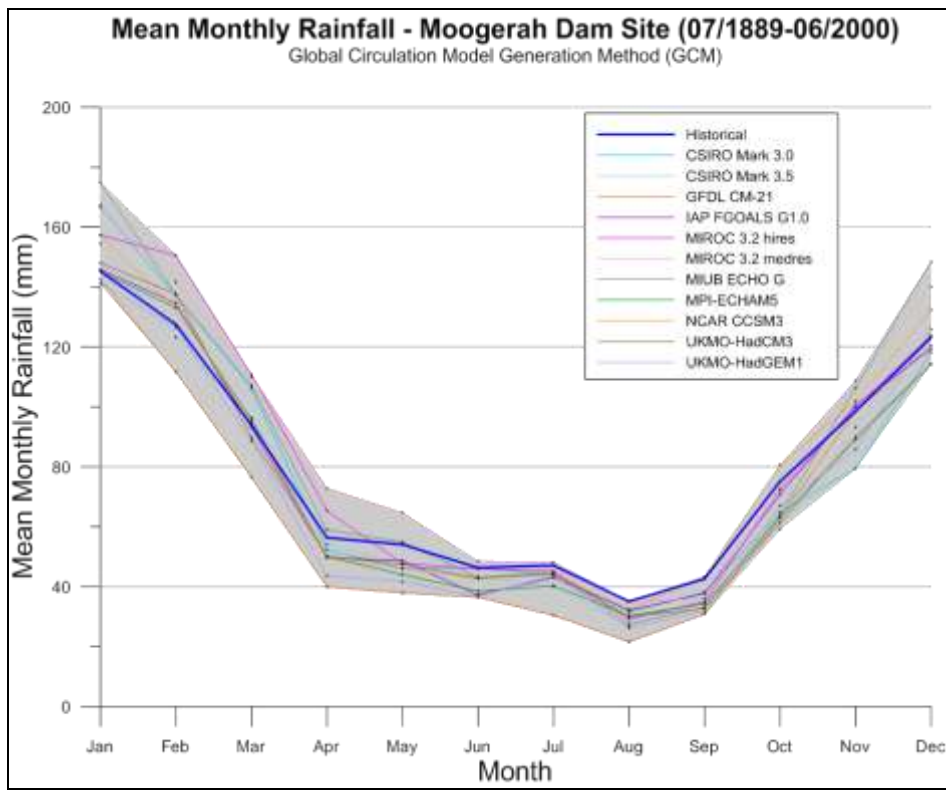


Figure D.1 Mean monthly climate change rainfall – GCM – Subarea B1 (Moogerah Dam Site).

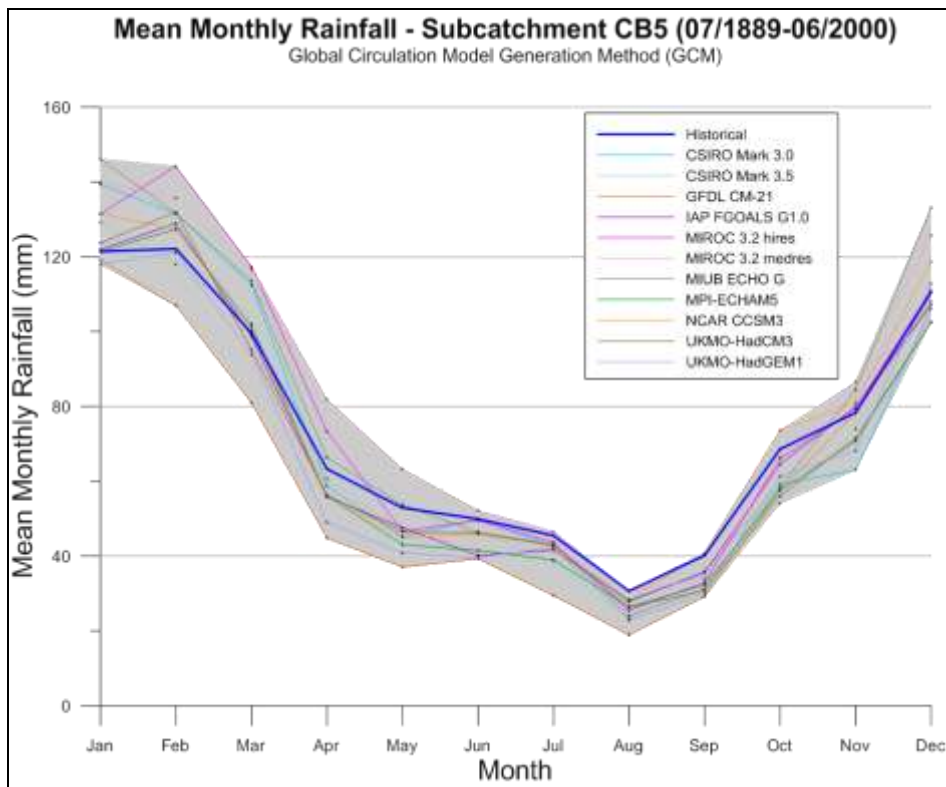


Figure D.2 Mean monthly climate change rainfall – GCM – Subarea CB5.

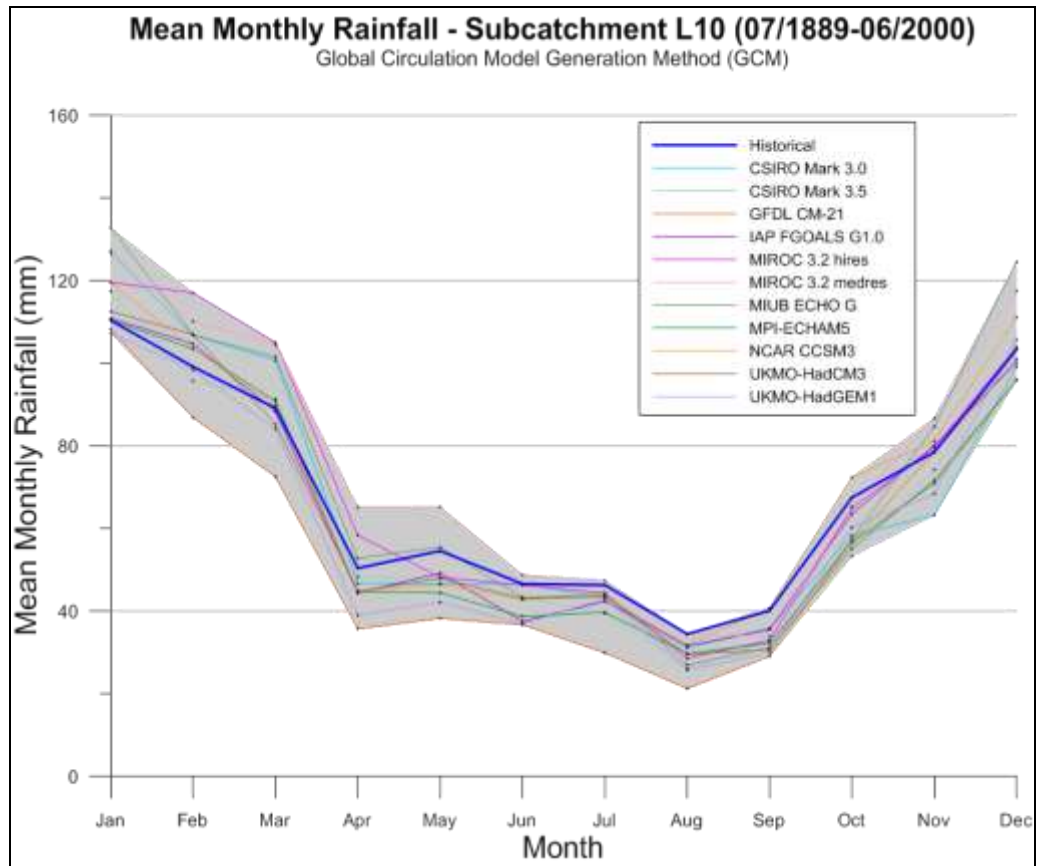


Figure D.3 Mean monthly climate change rainfall – GCM – Subarea L10.

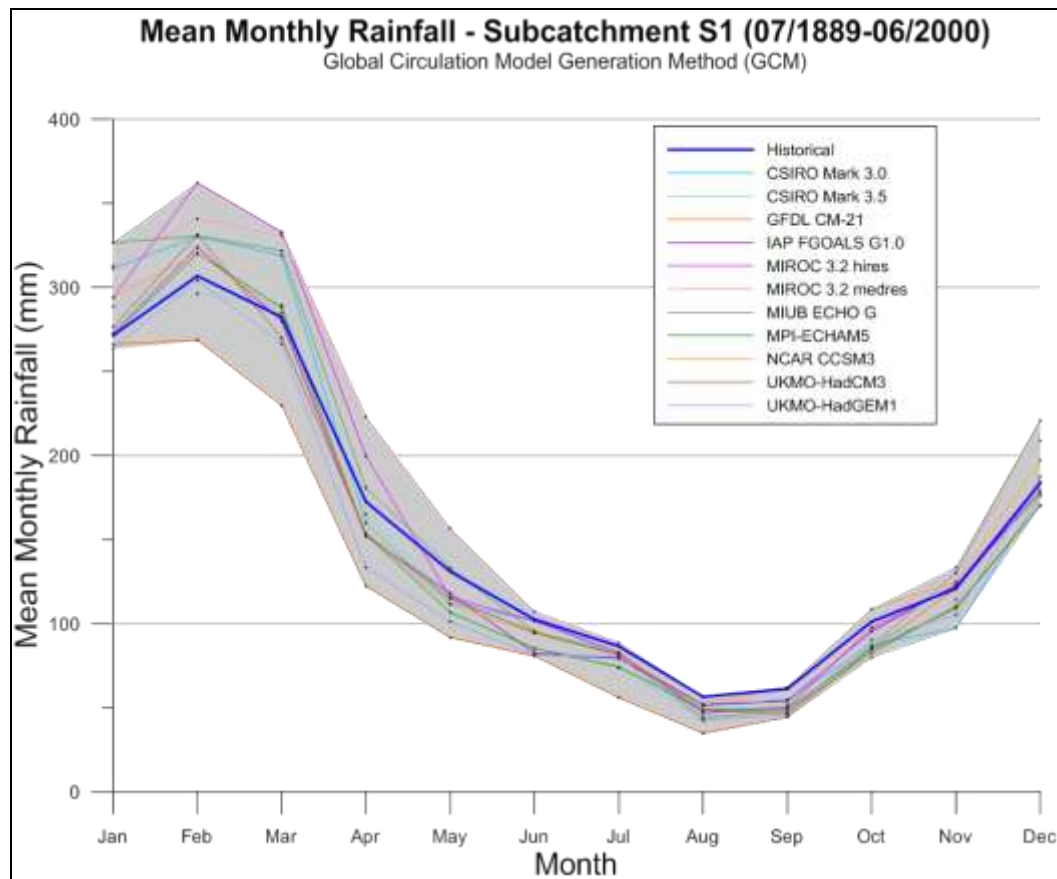


Figure D.4 Mean monthly climate change rainfall – GCM – Subarea S1.

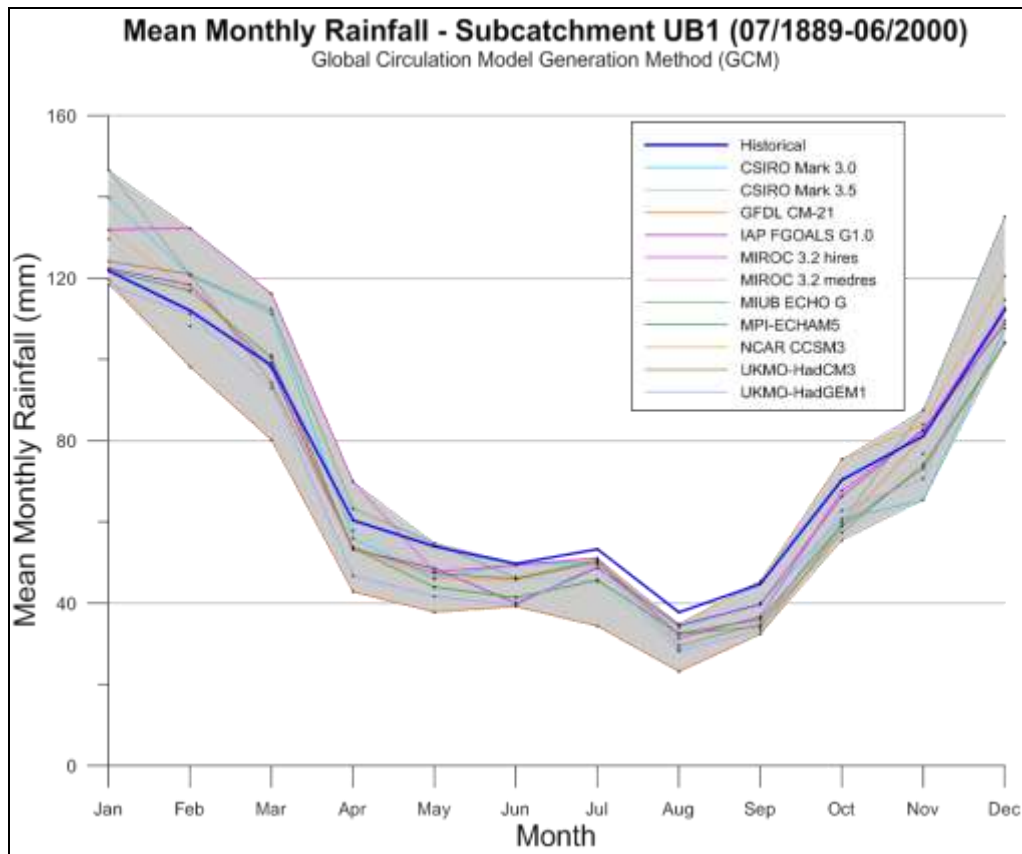


Figure D.5 Mean monthly climate change rainfall – GCM – Subarea UB1.

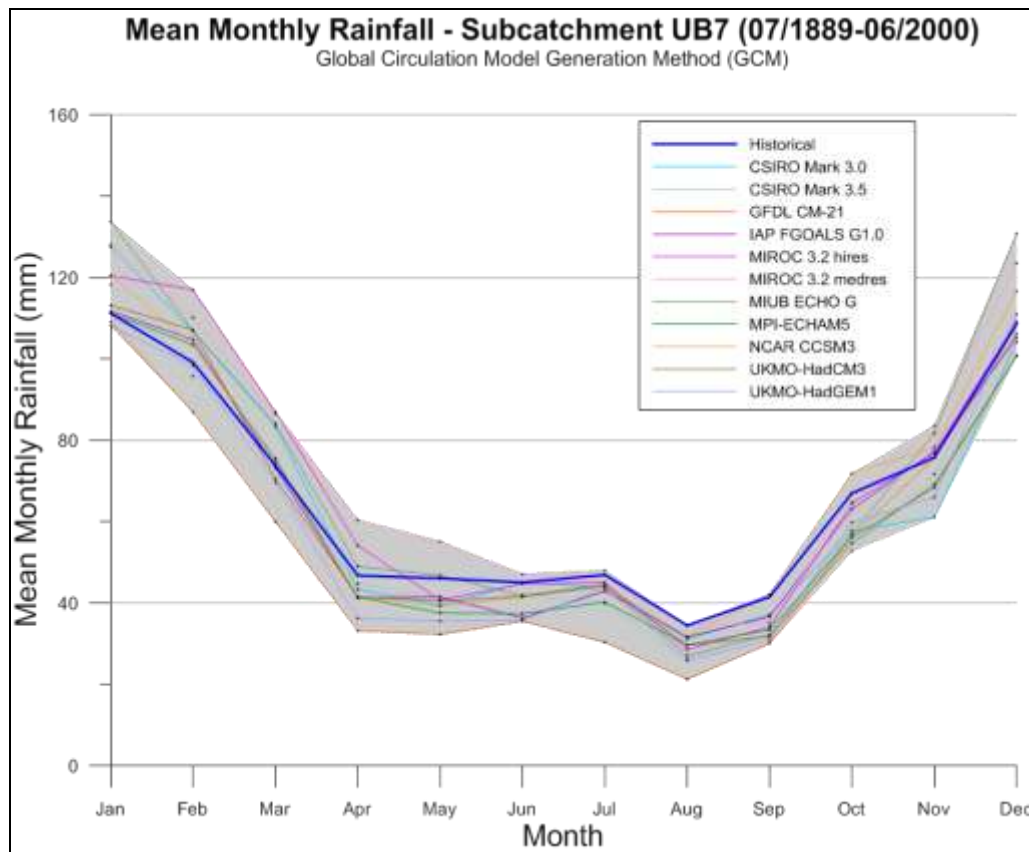


Figure D.6 Mean monthly climate change rainfall – GCM – Subarea UB7.

D.2 Downscaled Generation Method

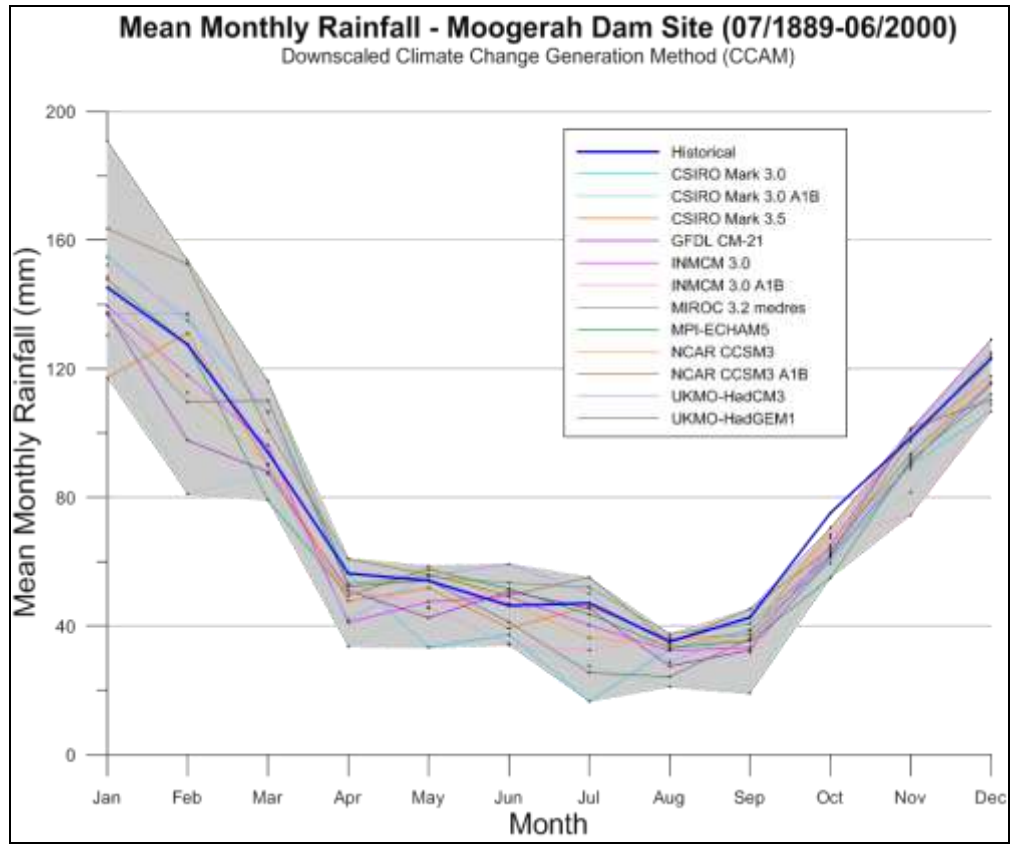


Figure D.7 Mean monthly climate change rainfall – CCAM – Subarea B1 (Moogerah Dam Site).

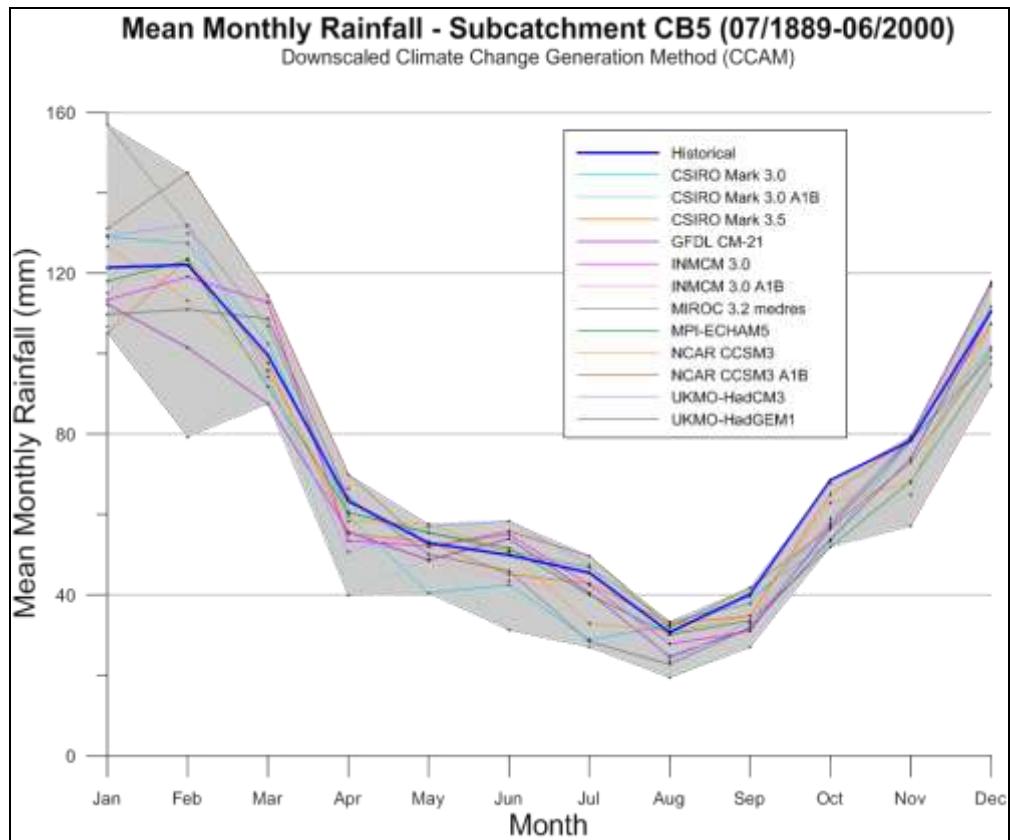


Figure D.8 Mean monthly climate change rainfall – CCAM – Subarea CB5.

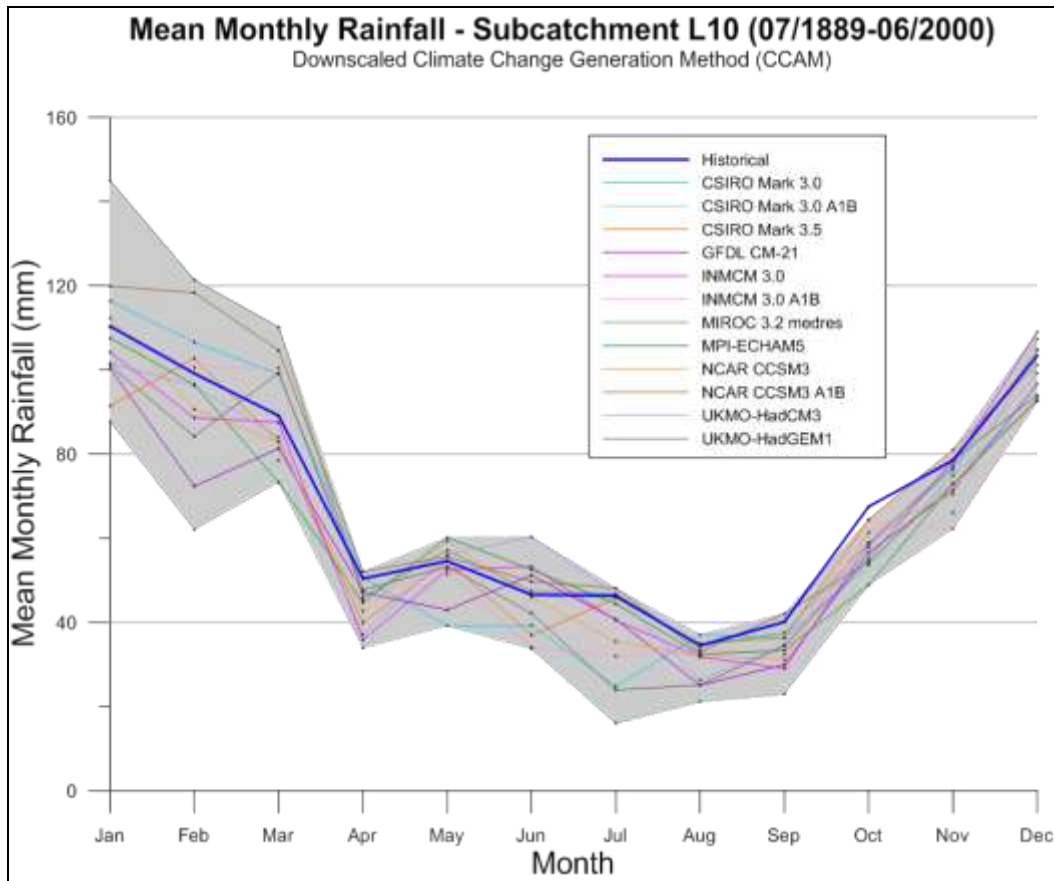


Figure D.9 Mean monthly climate change rainfall – CCAM – Subarea L10.

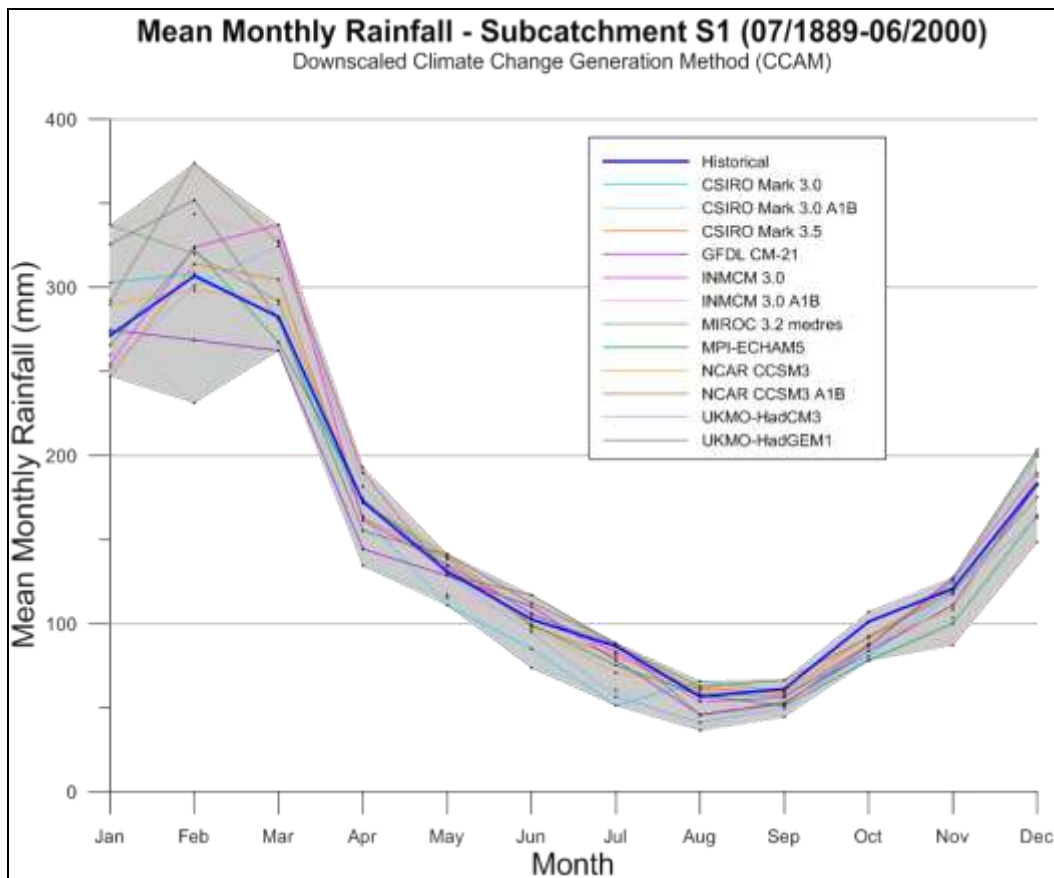


Figure D.10 Mean monthly climate change rainfall – CCAM – Subarea S1.

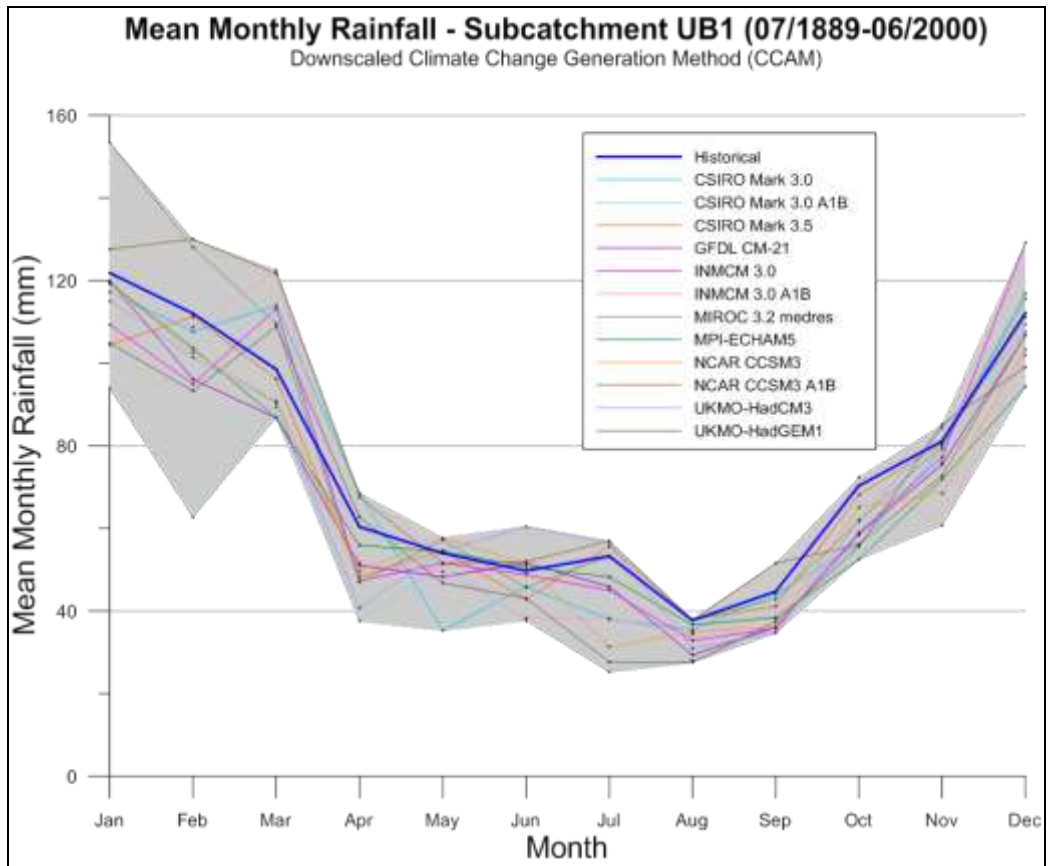


Figure D.11 Mean monthly climate change rainfall – CCAM – Subarea UB1.

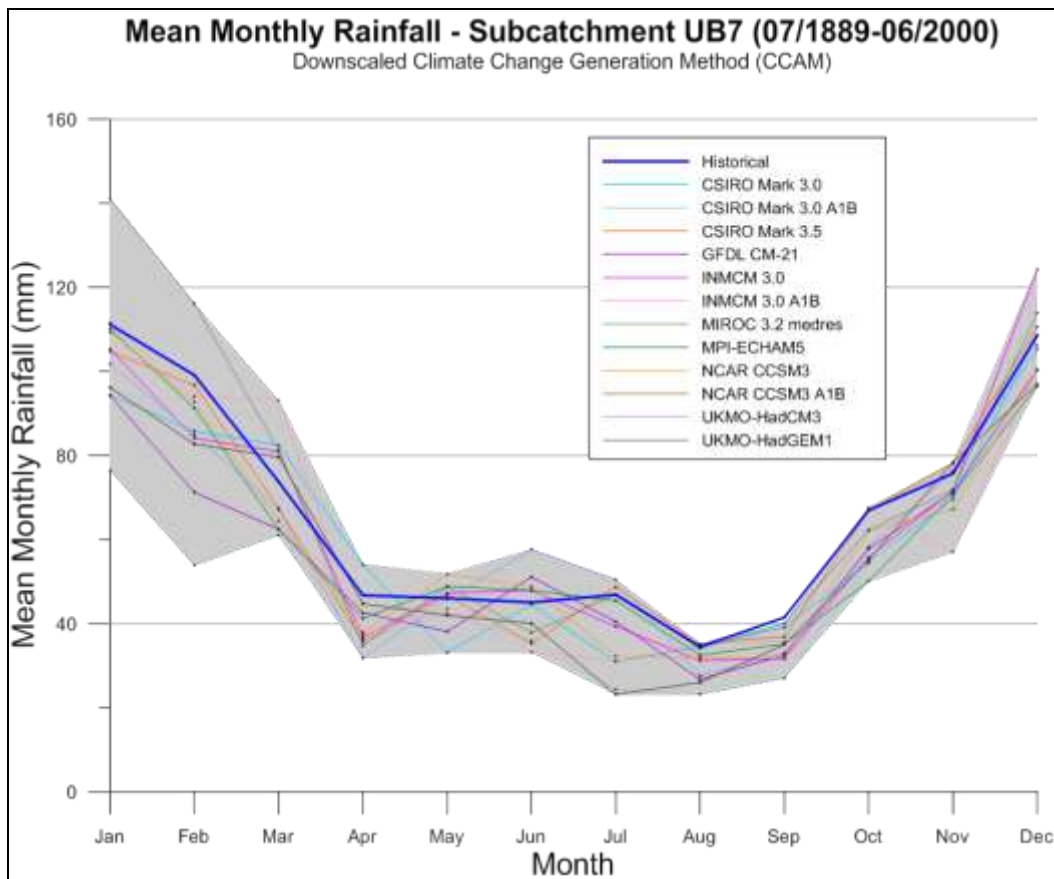


Figure D.12 Mean monthly climate change rainfall – CCAM – Subarea UB7.

D.3 Comparison of Generation Methods

D.3.1 GCM and CCAM

Table 7.17 Description of Relevant Generation Methods.

Generation Method	Gridsize	Description
GCM	Ranging from 100 to 400km	Global circulation models developed by various research institutes around the world
CCAM	~20km	Original dynamically downscaled models using the Conformal-Cubic Atmospheric Model (CCAM) – downscaled to 20km

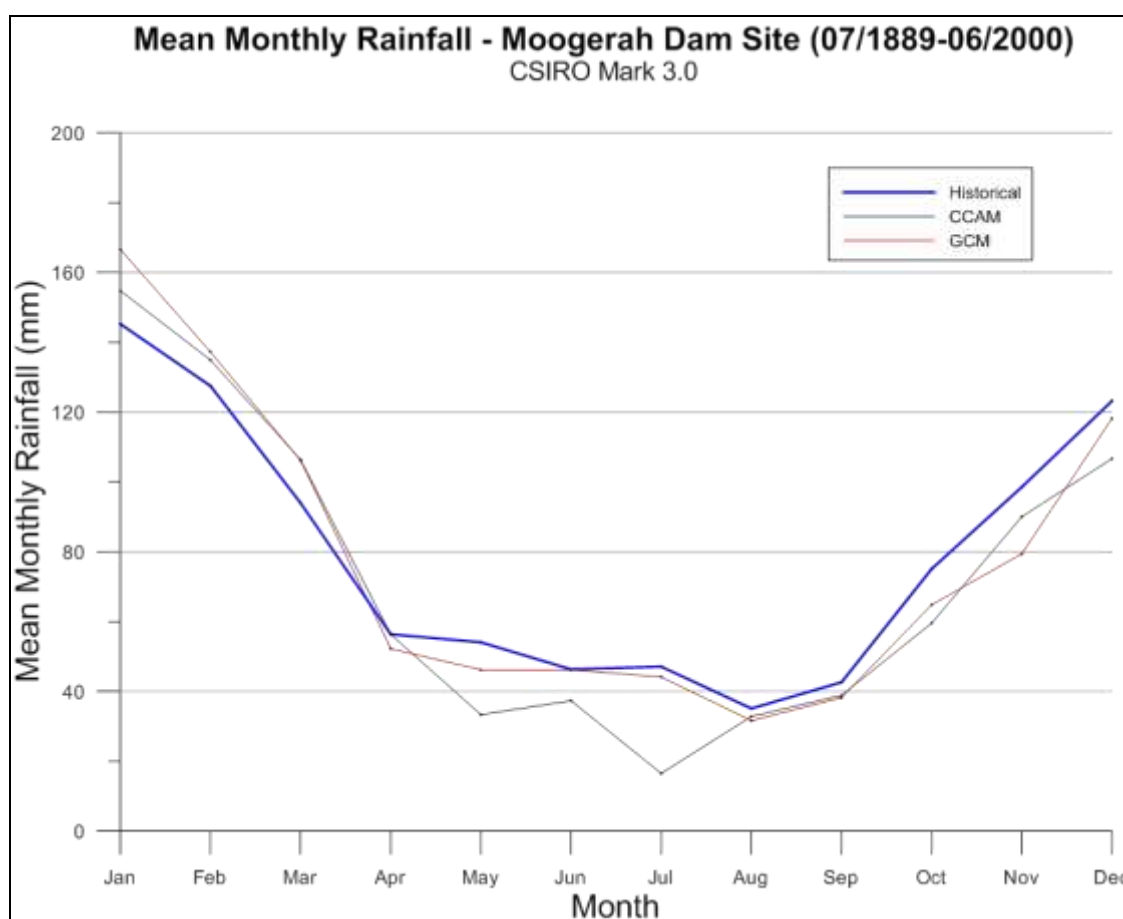


Figure D.13 Mean monthly climate change rainfall – comparison of generation methods for CSIRO Mark 3.0 (GCM and CCAM) – Subarea B1 (Moogerah Dam Site).

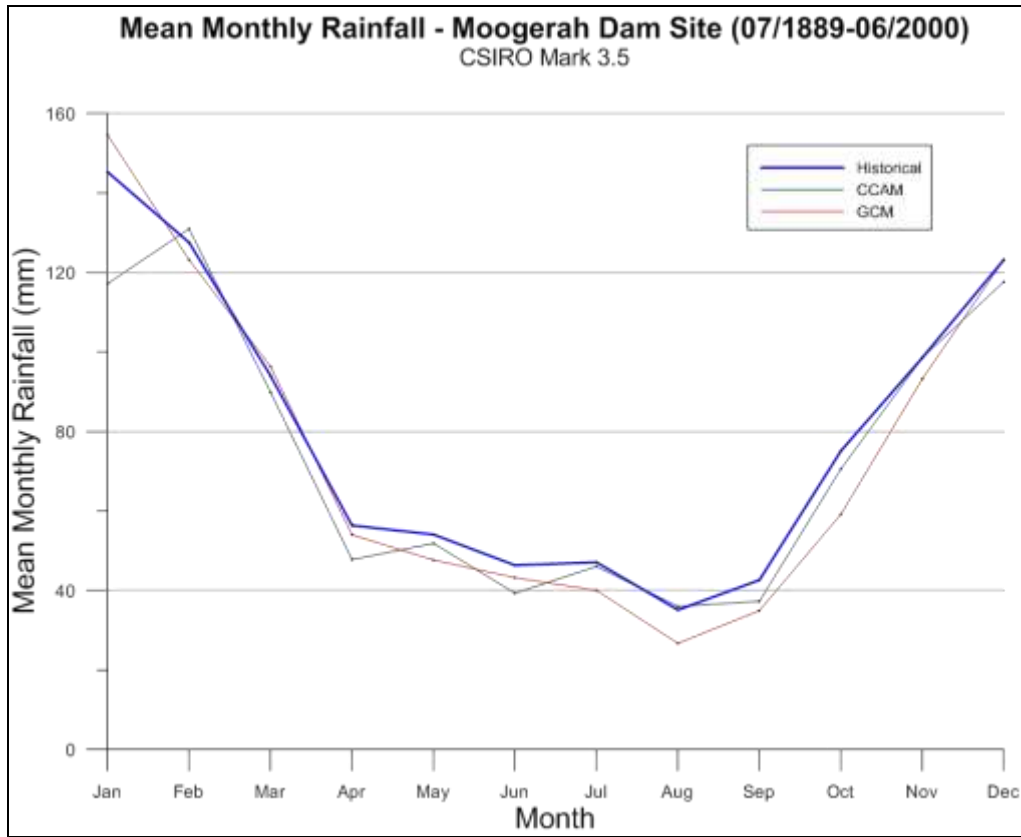


Figure D.14. Mean monthly climate change rainfall – comparison of generation methods for CSIRO Mark 3.5 (GCM and CCAM) – Subarea B1 (Moogerah Dam Site).

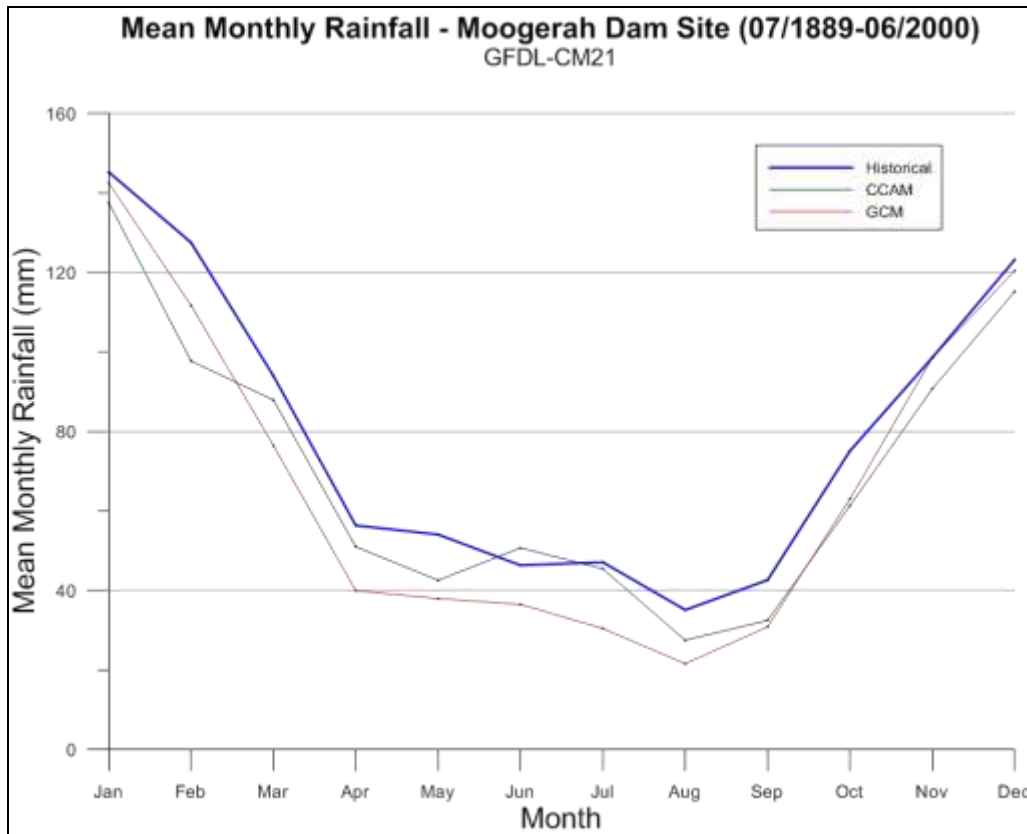


Figure D.15 Mean monthly climate change rainfall – comparison of generation methods for GFDL CM21 (GCM and CCAM) – Subarea B1 (Moogerah Dam Site).

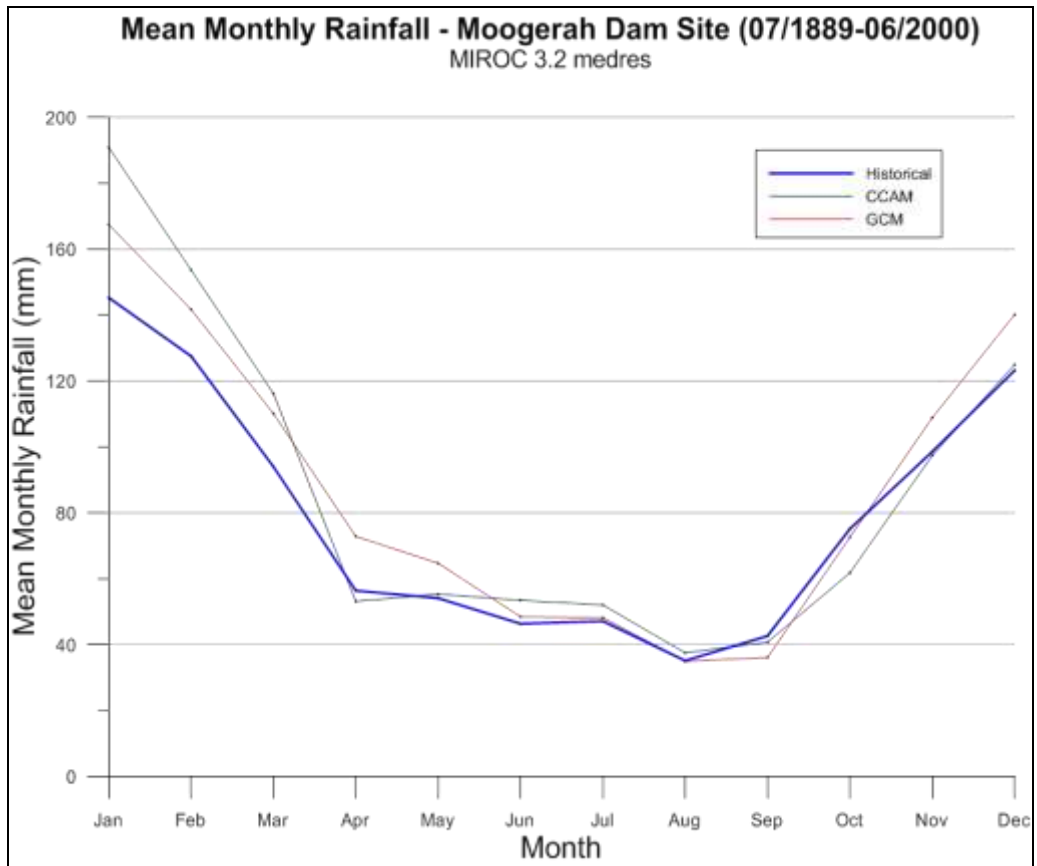


Figure D.16 Mean monthly climate change rainfall – comparison of generation methods for MIROC 3.2 medres (GCM and CCAM) – Subarea B1 (Moogerah Dam Site).

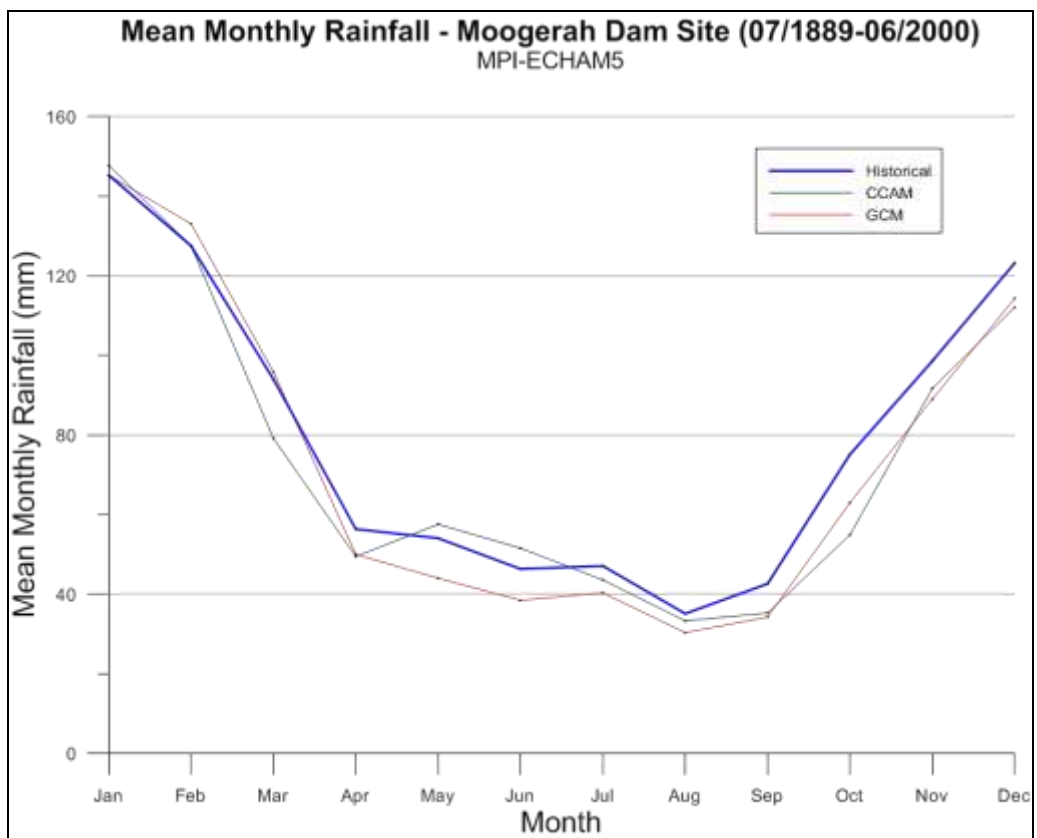


Figure D.17 Mean monthly climate change rainfall – comparison of generation methods for MPI ECHAM5 (GCM and CCAM) – Subarea B1 (Moogerah Dam Site).

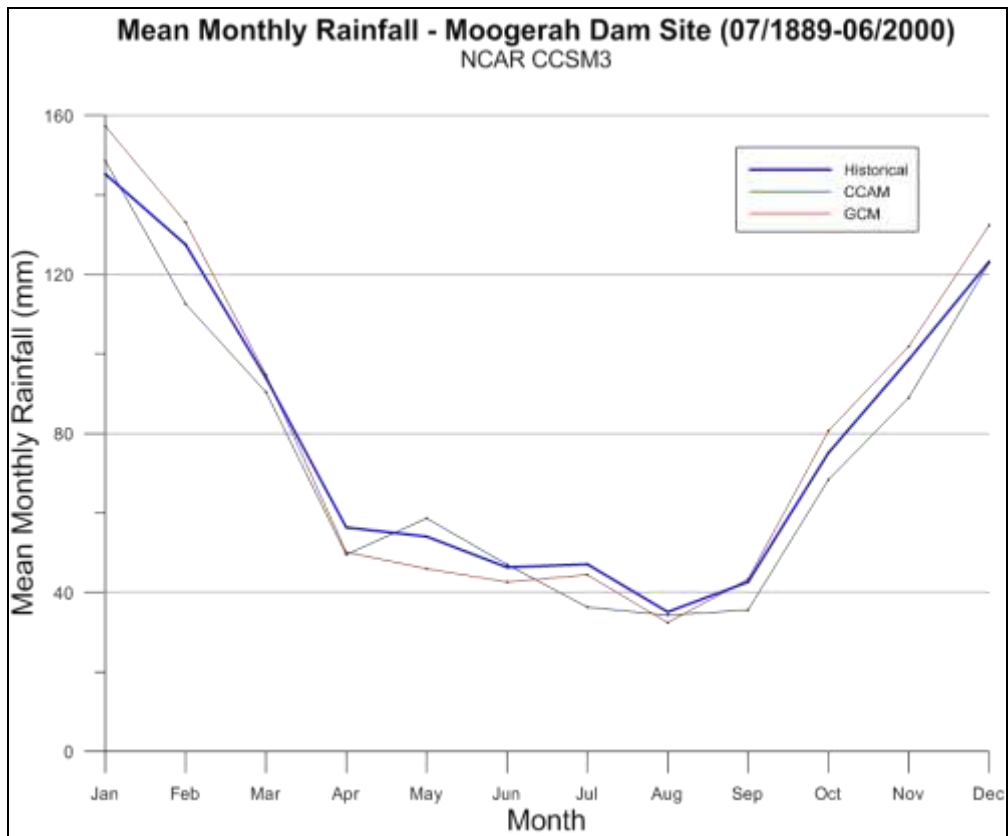


Figure D.18 Mean monthly climate change rainfall – comparison of generation methods for NCAR CCSM3 (GCM and CCAM) – Subarea B1 (Moogerah Dam Site).

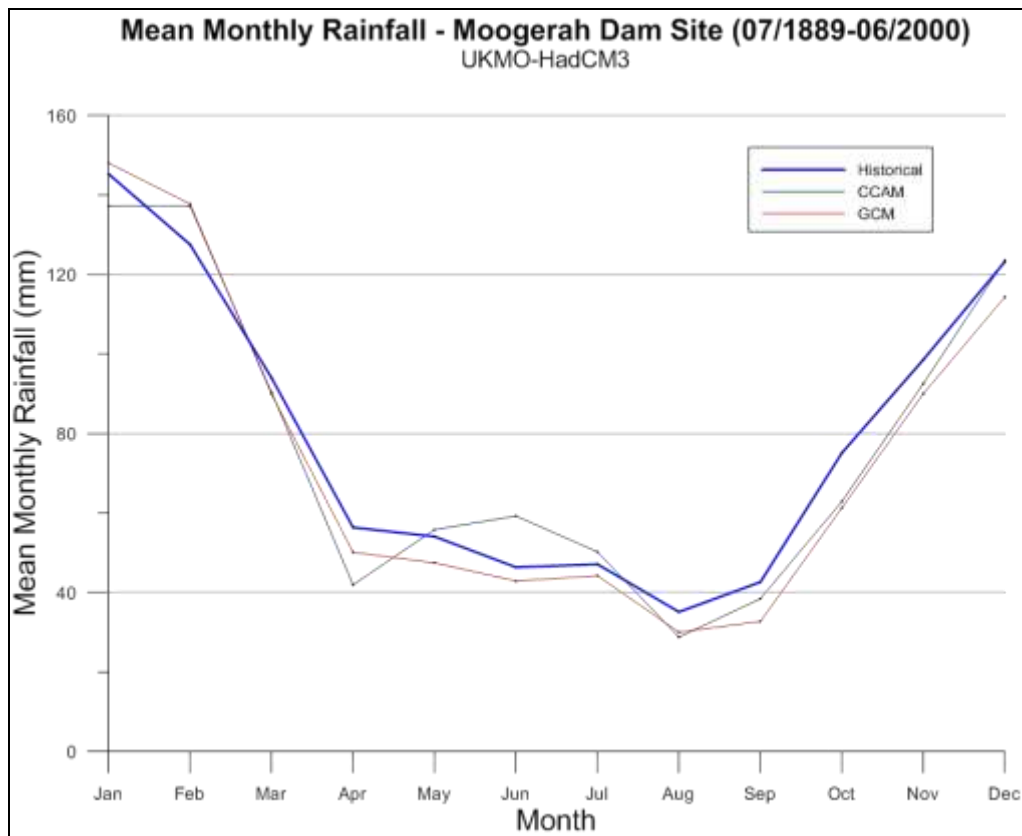


Figure D.19 Mean monthly climate change rainfall – comparison of generation methods for UKMO HadCM3 (GCM and CCAM) – Subarea B1 (Moogerah Dam Site).

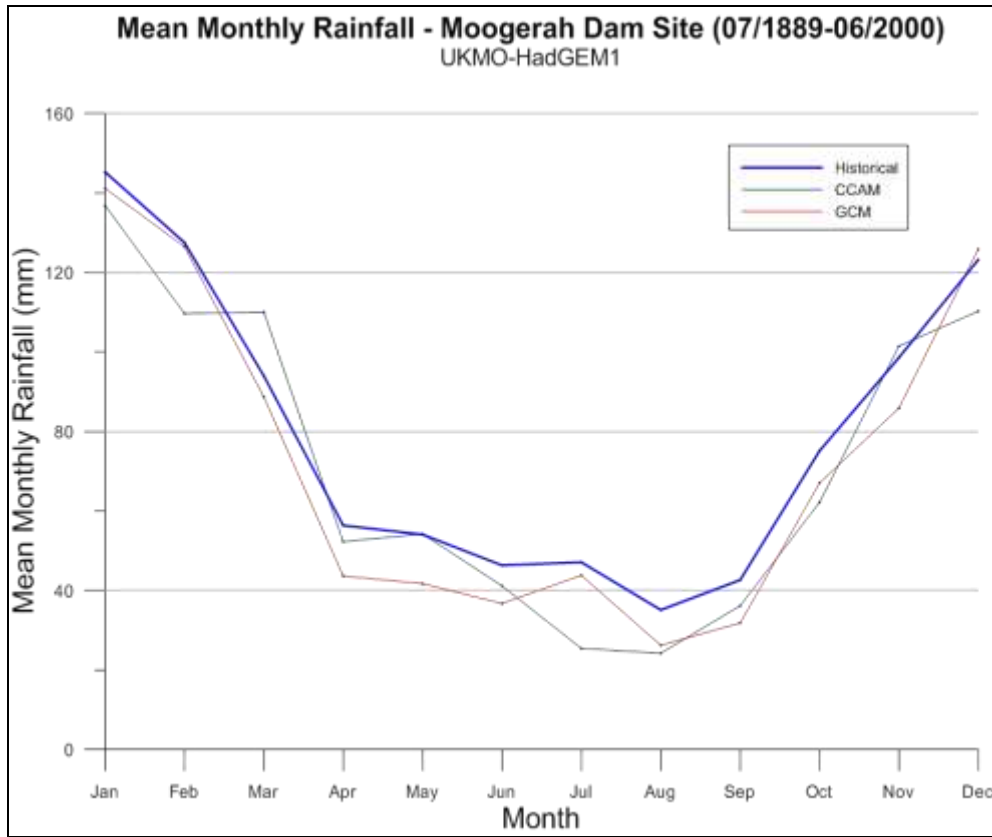


Figure D.20 Mean monthly climate change rainfall – comparison of generation methods for UKMO HadGEM1 (GCM and CCAM) – Subarea B1 (Moogerah Dam Site).

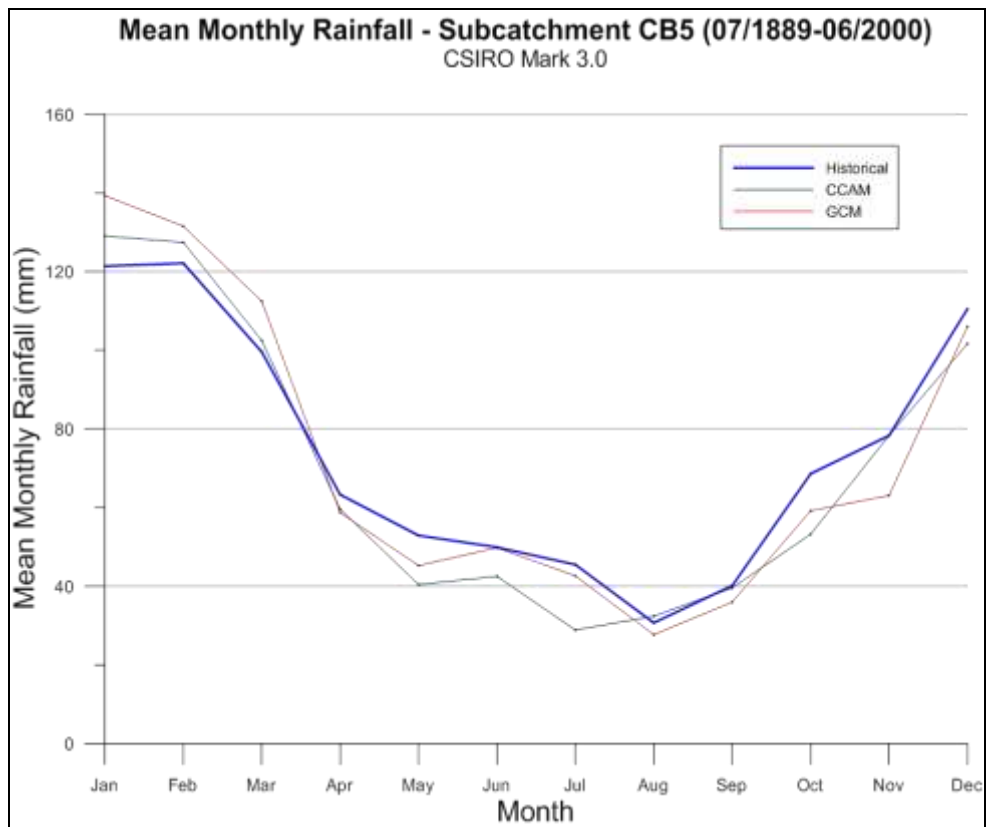


Figure D.21 Mean monthly climate change rainfall – comparison of generation methods for CSIRO Mark 3.0 (GCM and CCAM) – Subarea CB5.

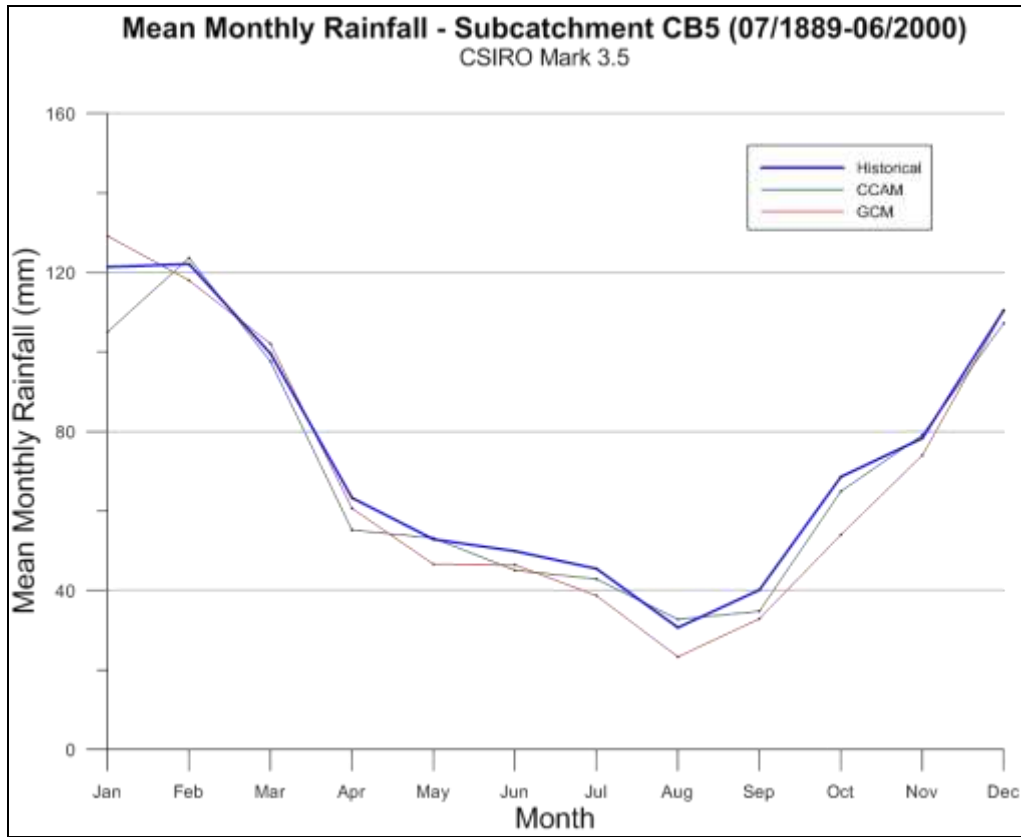


Figure D.22 Mean monthly climate change rainfall – comparison of generation methods for CSIRO Mark 3.5 (GCM and CCAM) – Subarea CB5.

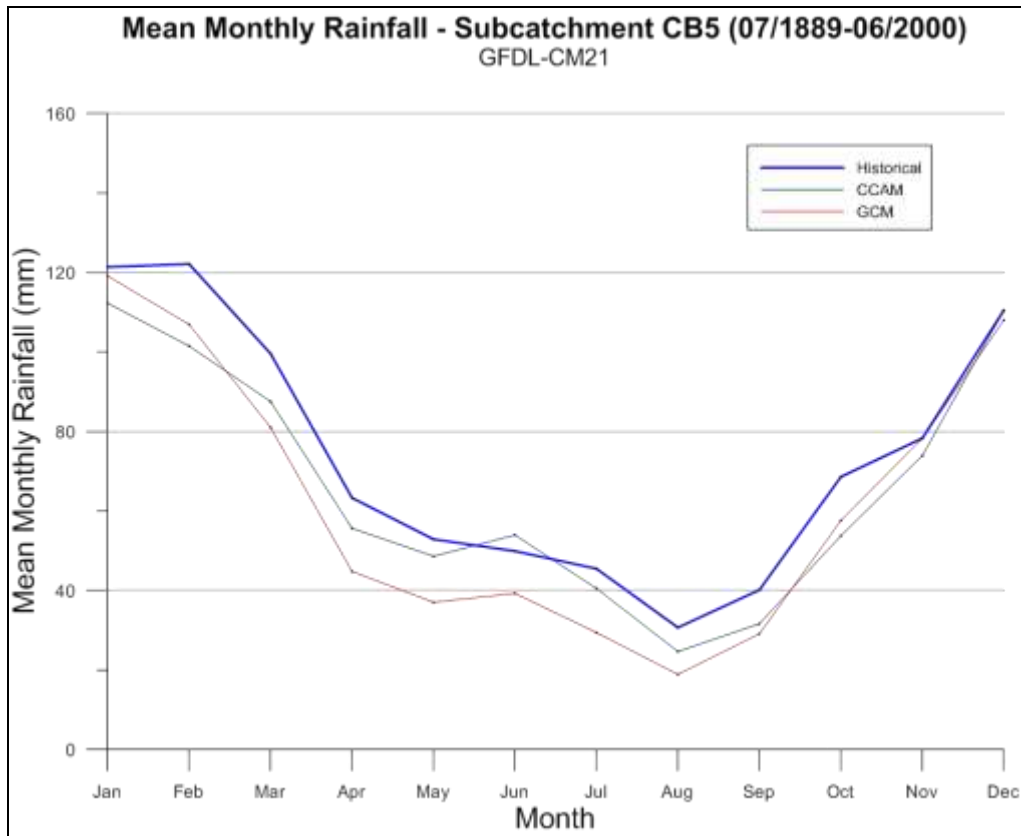


Figure D.23 Mean monthly climate change rainfall – comparison of generation methods for GFDL CM21 (GCM and CCAM) – Subarea CB5.

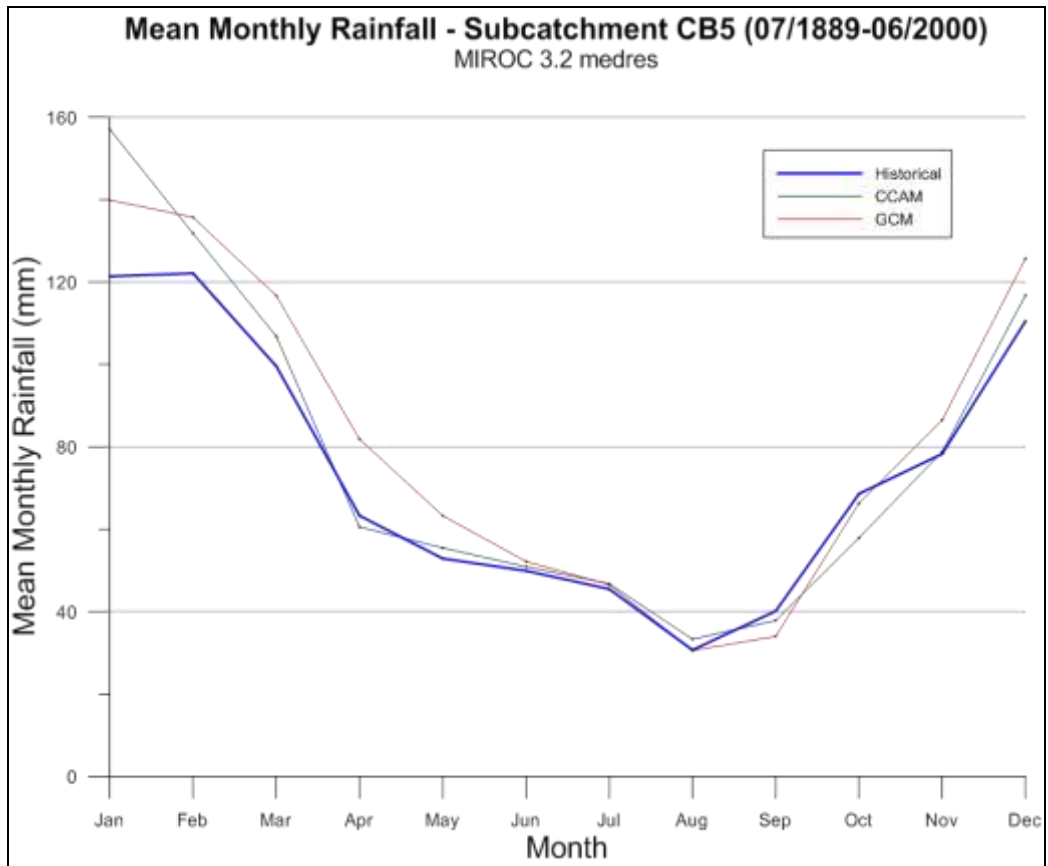


Figure D.24 Mean monthly climate change rainfall – comparison of generation methods for MIROC 3.2 medres (GCM and CCAM) – Subarea CB5.

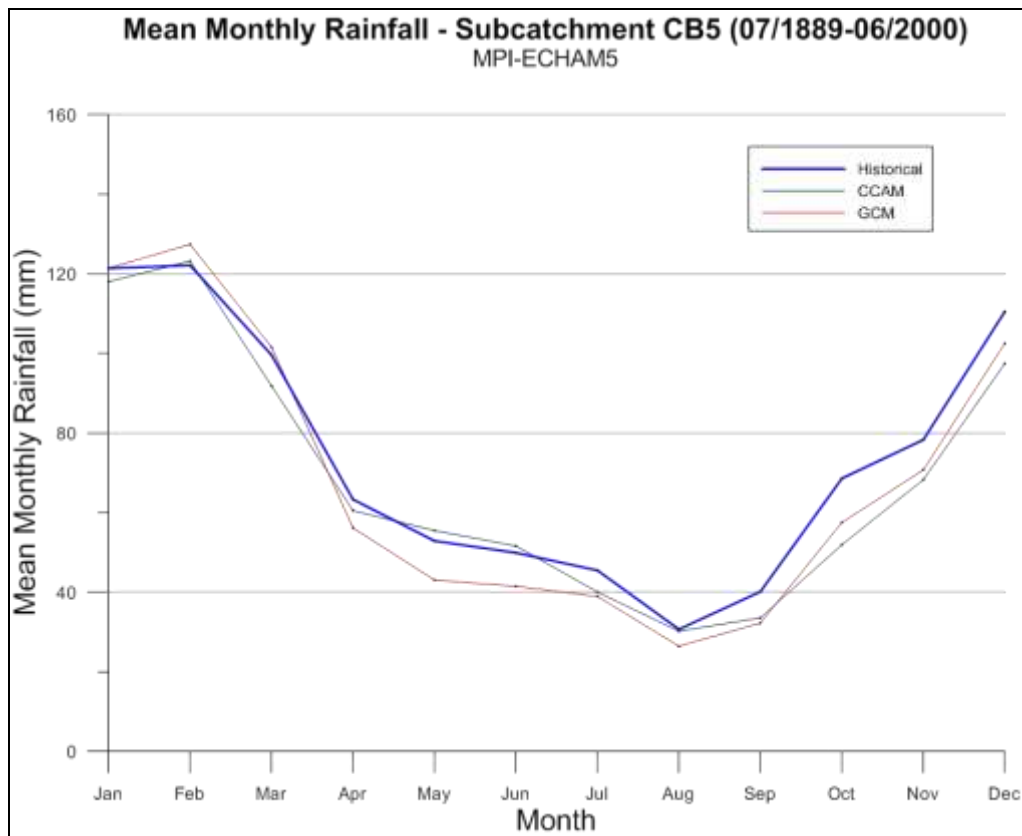


Figure D.25 Mean monthly climate change rainfall – comparison of generation methods for MPI ECHAM5 (GCM and CCAM) – Subarea CB5.

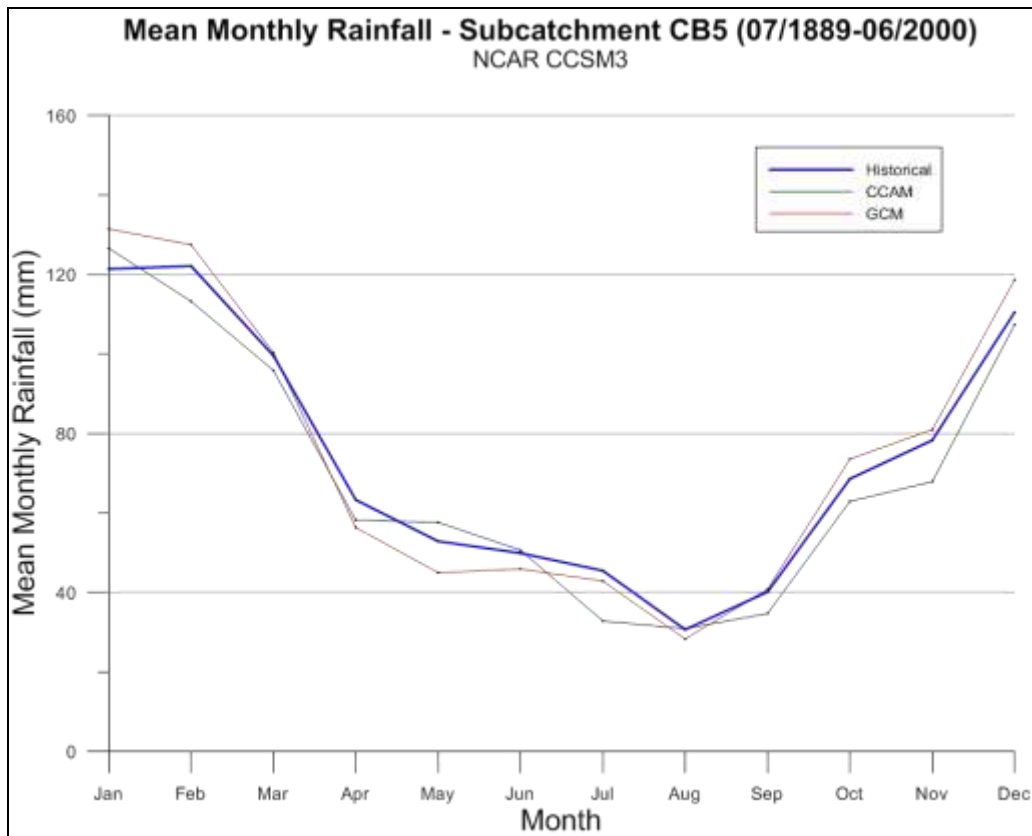


Figure D.26 Mean monthly climate change rainfall – comparison of generation methods for NCAR CCSM3 (GCM and CCAM) – Subarea CB5.

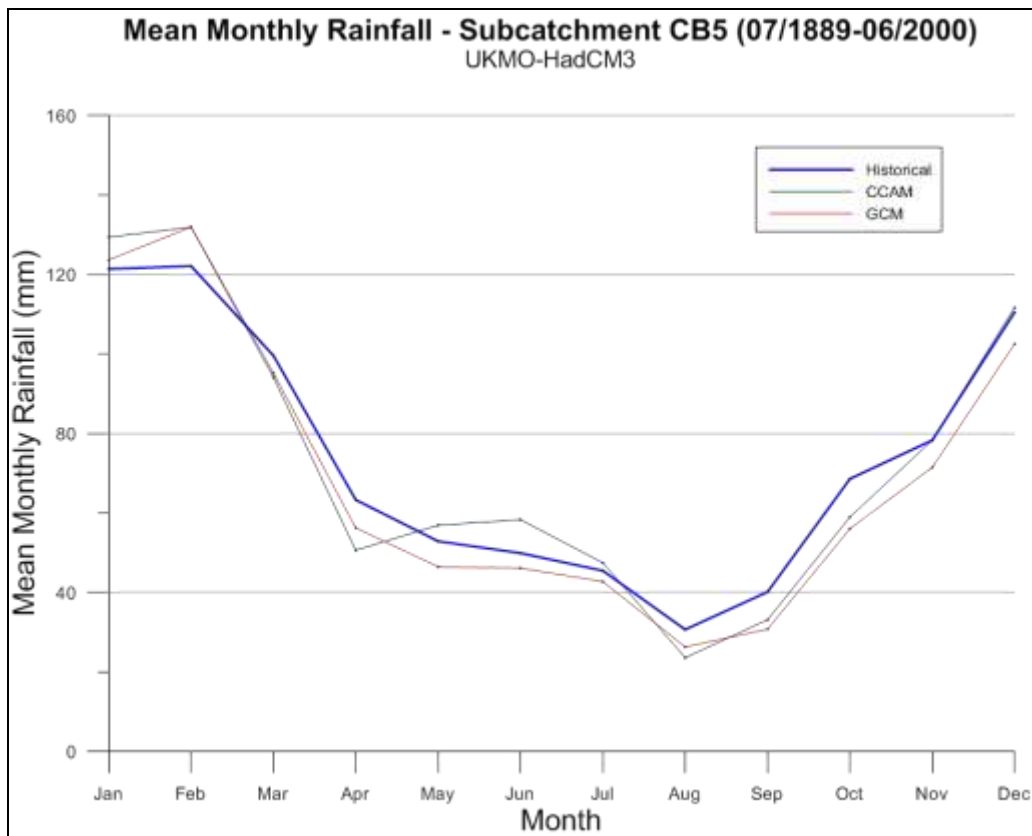


Figure D.27 Mean monthly climate change rainfall – comparison of generation methods for UKMO HadCM3 (GCM and CCAM) – Subarea CB5.

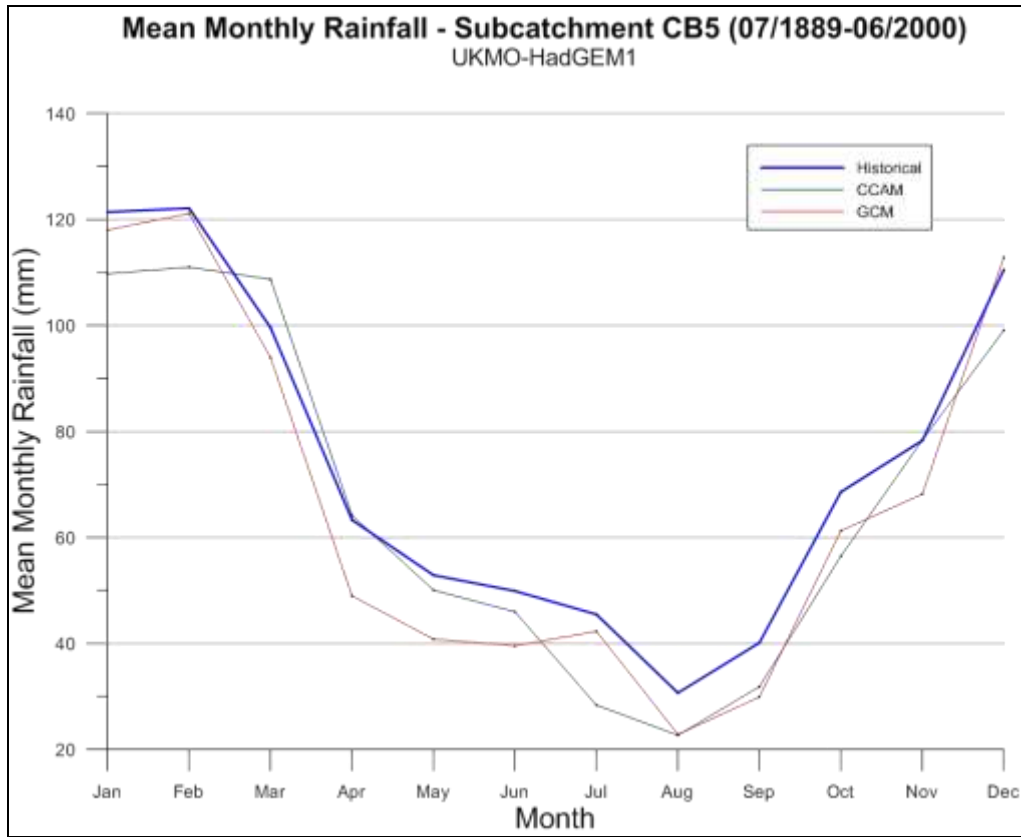


Figure D.28 Mean monthly climate change rainfall – comparison of generation methods for UKMO HadGEM1 (GCM and CCAM) – Subarea CB5.

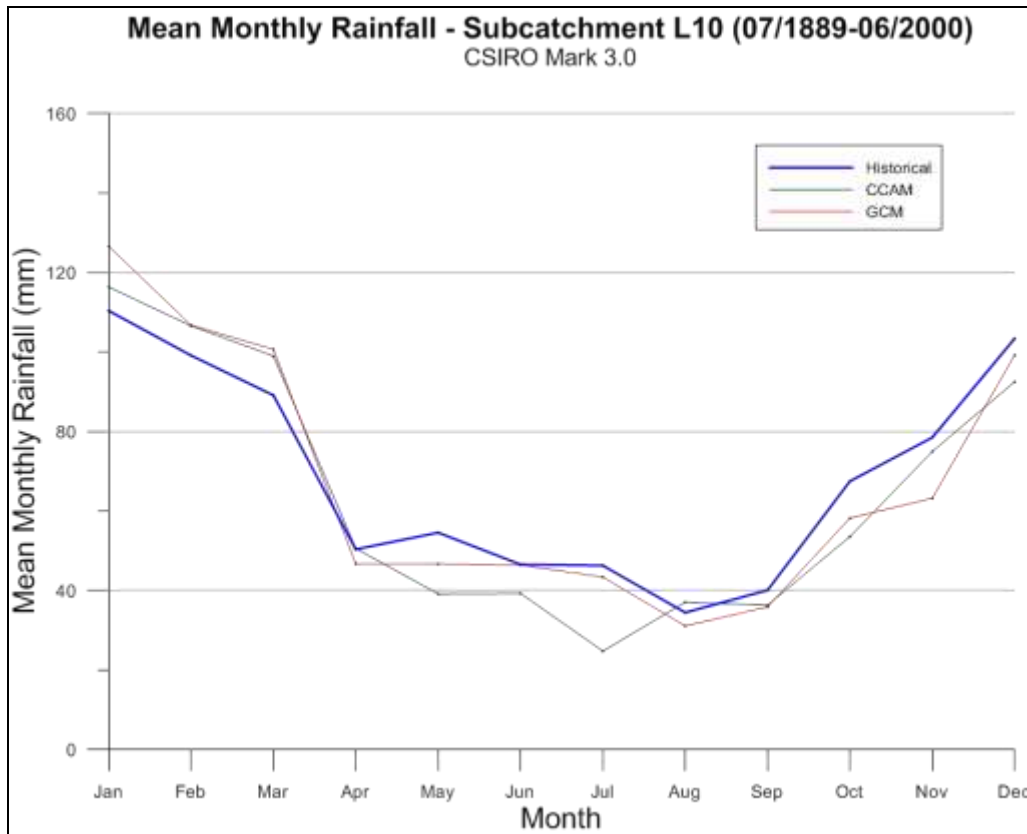


Figure D.29 Mean monthly climate change rainfall – comparison of generation methods for CSIRO Mark 3.0 (GCM and CCAM) – Subarea L10.

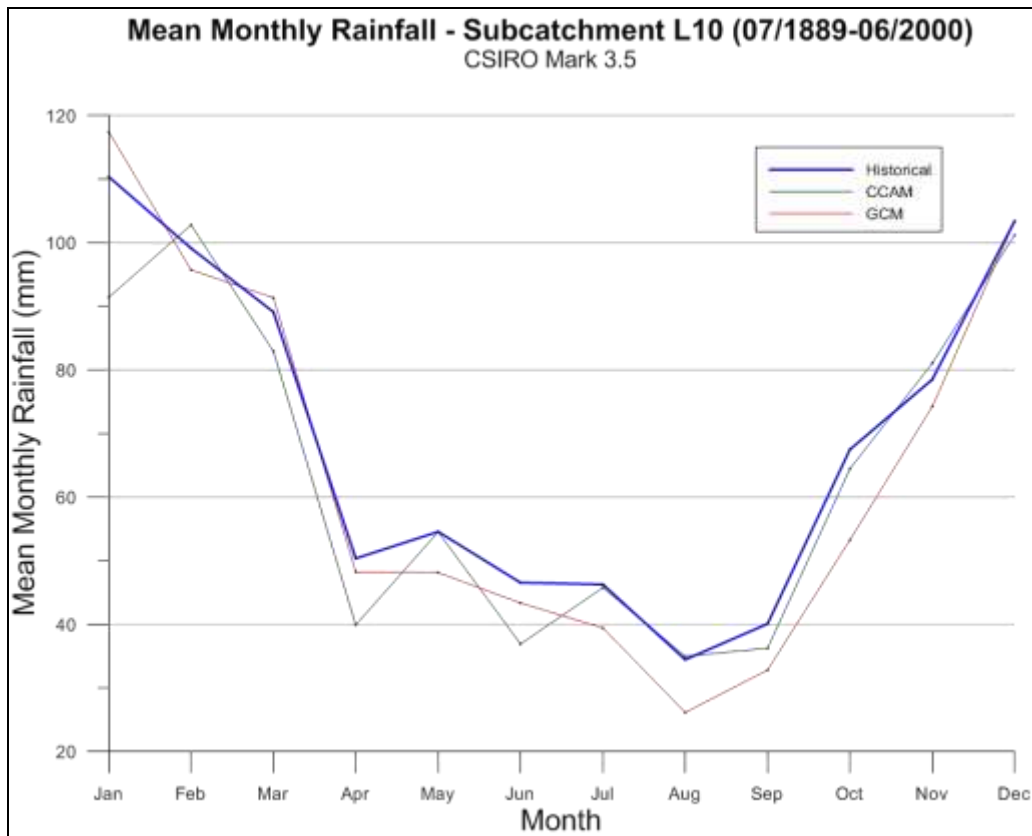


Figure D.30 Mean monthly climate change rainfall – comparison of generation methods for CSIRO Mark 3.5 (GCM and CCAM) – Subarea L10.

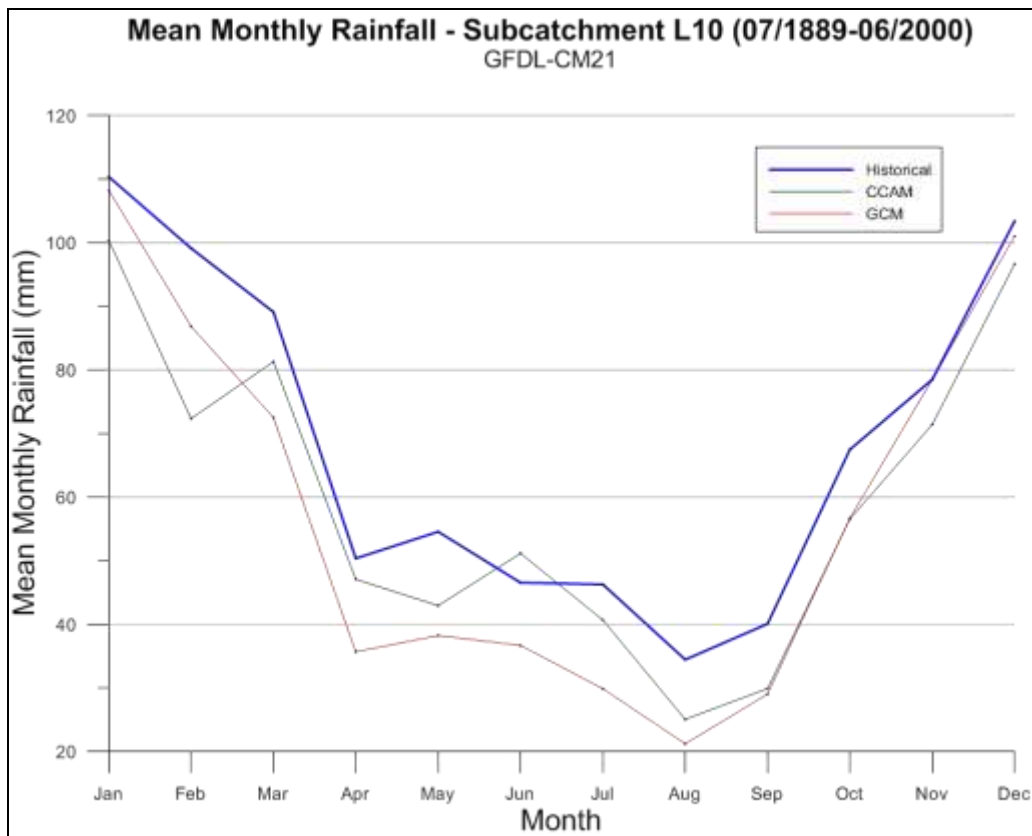


Figure D.31 Mean monthly climate change rainfall – comparison of generation methods for GFDL CM21 (GCM and CCAM) – Subarea L10.

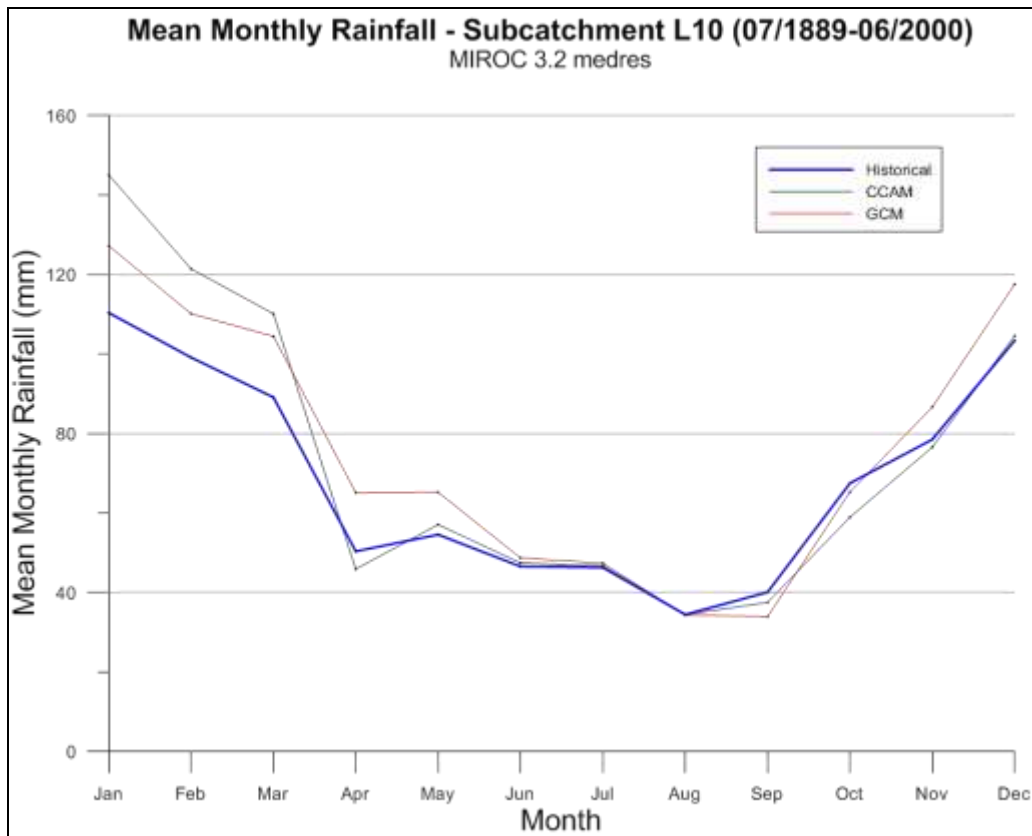


Figure D.32 Mean monthly climate change rainfall – comparison of generation methods for MIROC 3.2 medres (GCM and CCAM) – Subarea L10.

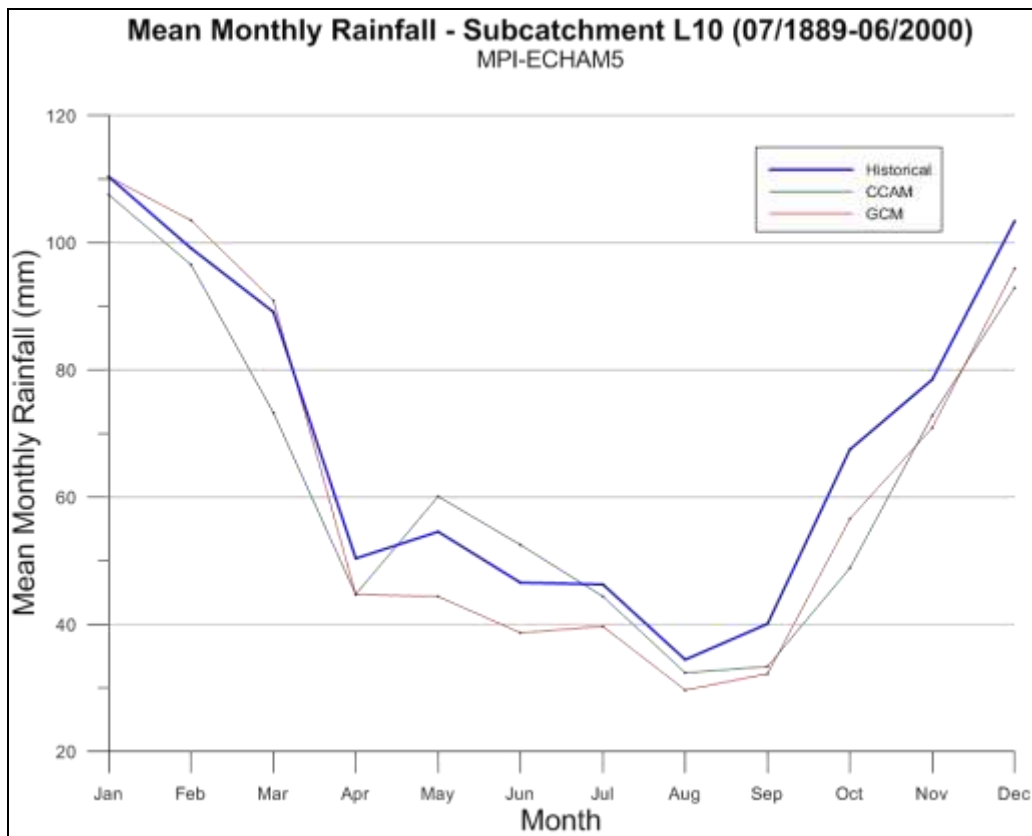


Figure D.33 Mean monthly climate change rainfall – comparison of generation methods for MPI ECHAM5 (GCM and CCAM) – Subarea L10.

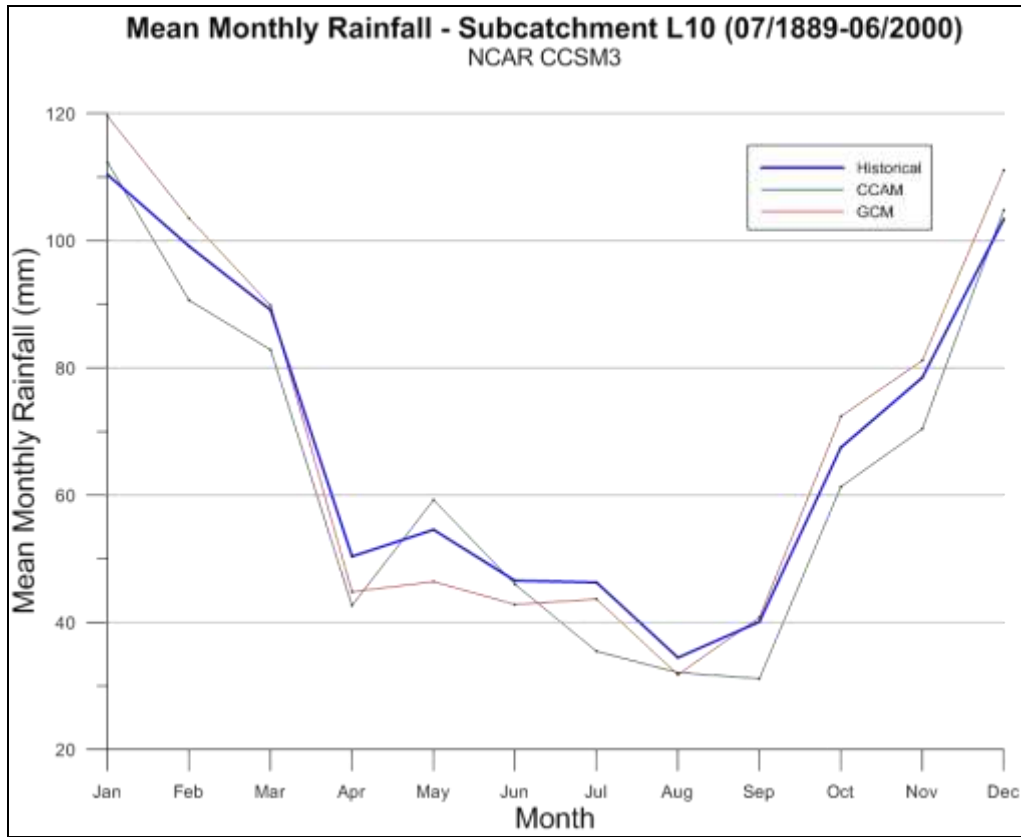


Figure D.34 Mean monthly climate change rainfall – comparison of generation methods for NCAR CCSM3 (GCM and CCAM) – Subarea L10.

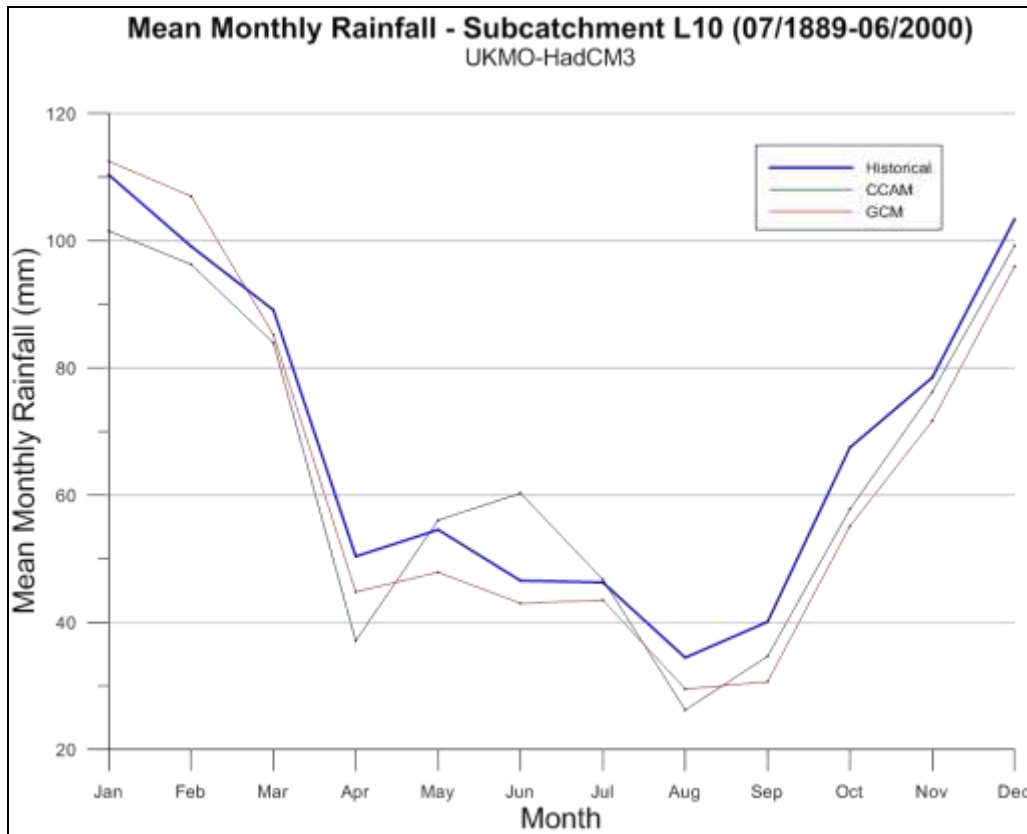


Figure D.35 Mean monthly climate change rainfall – comparison of generation methods for UKMO HadCM3 (GCM and CCAM) – Subarea L10.

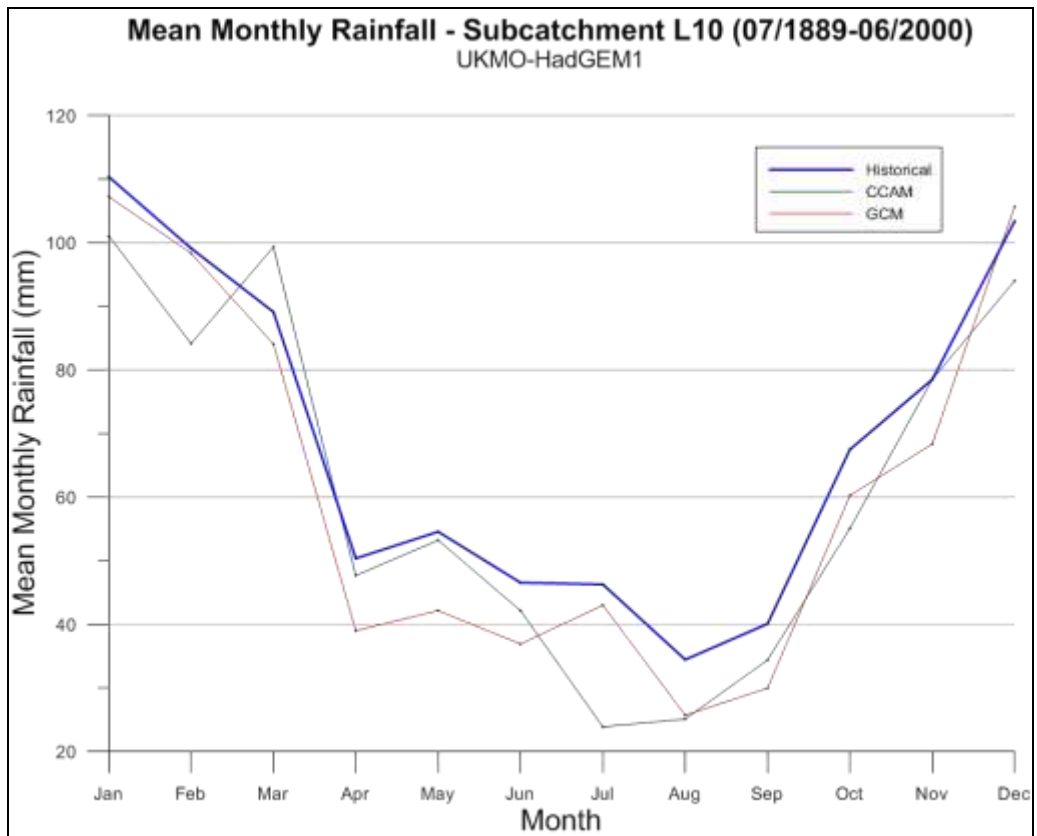


Figure D.36 Mean monthly climate change rainfall – comparison of generation methods for UKMO HadGEM1 (GCM and CCAM) – Subarea L10.

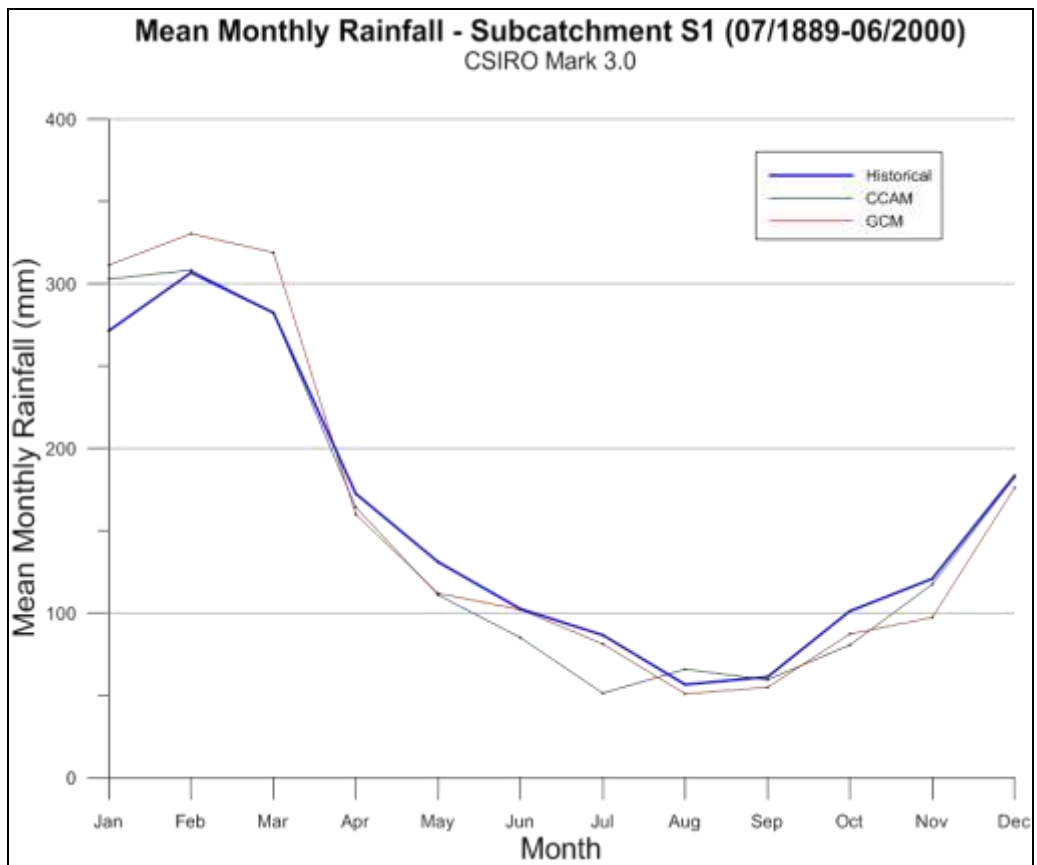


Figure D.37 Mean monthly climate change rainfall – comparison of generation methods for CSIRO Mark 3.0 (GCM and CCAM) – Subarea S1.

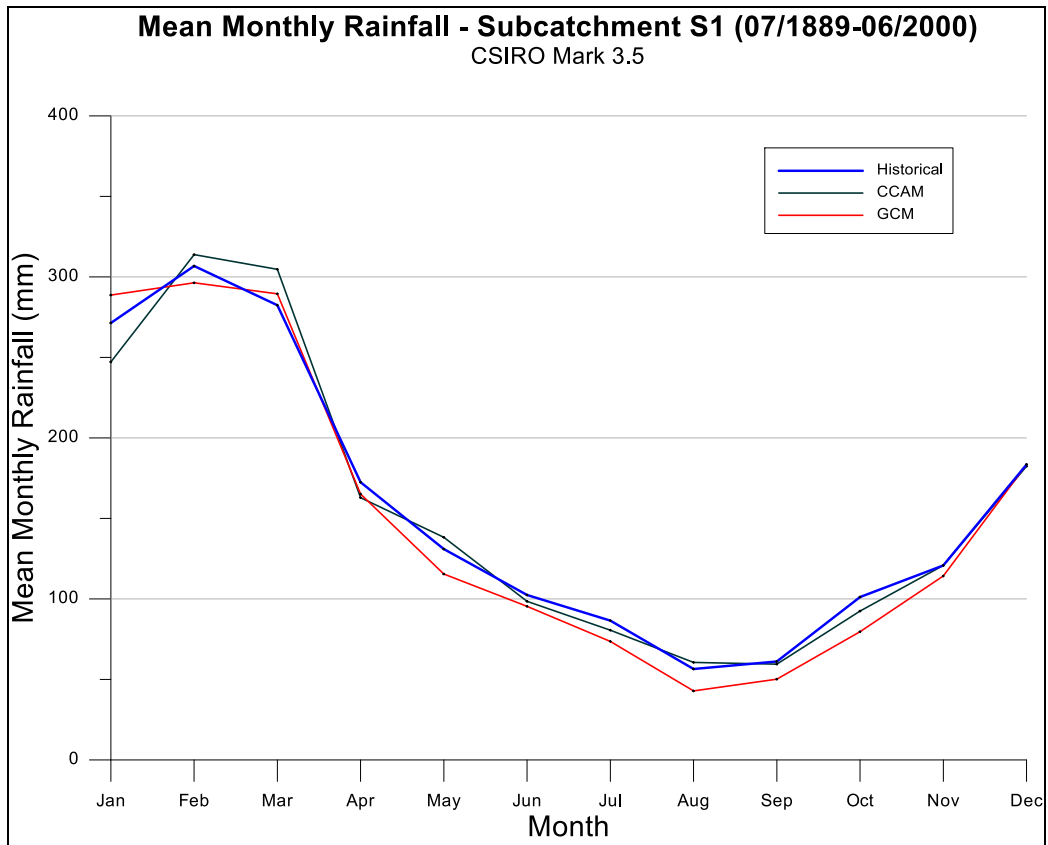


Figure D.38 Mean monthly climate change rainfall – comparison of generation methods for CSIRO Mark 3.5 (GCM and CCAM) – Subarea S1.

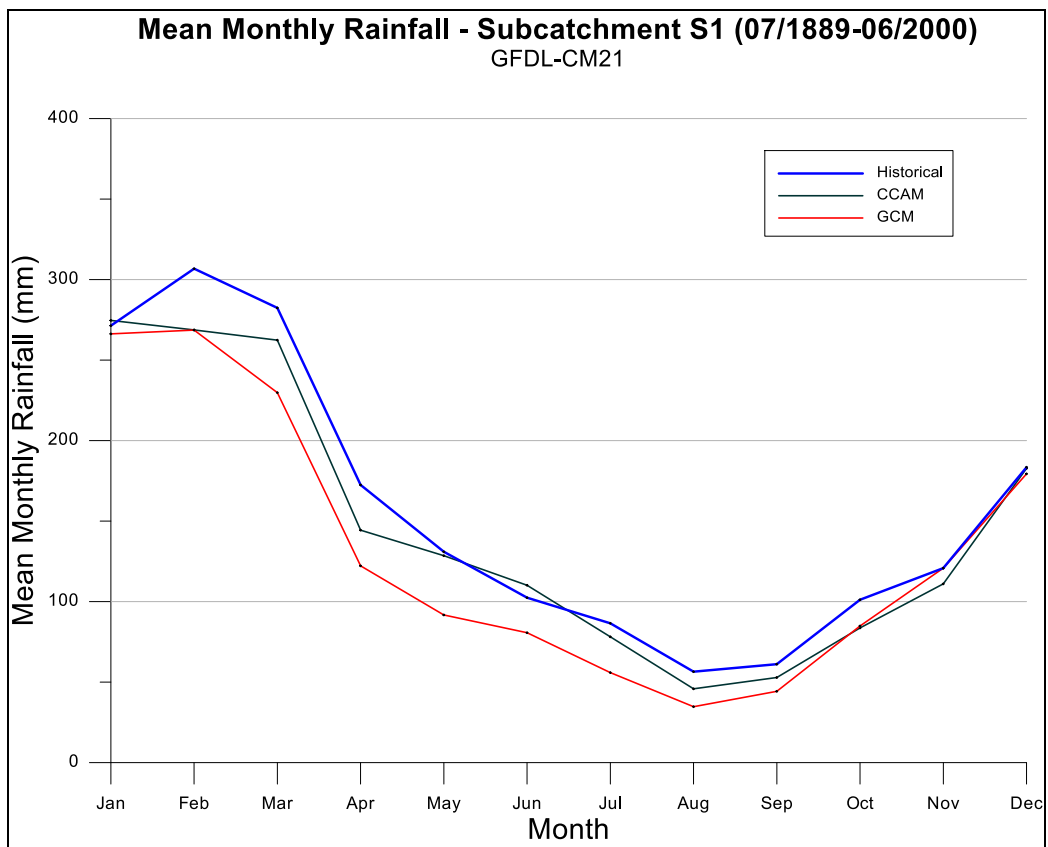


Figure D.39 Mean monthly climate change rainfall – comparison of generation methods for GFDL CM21 (GCM and CCAM) – Subarea S1.

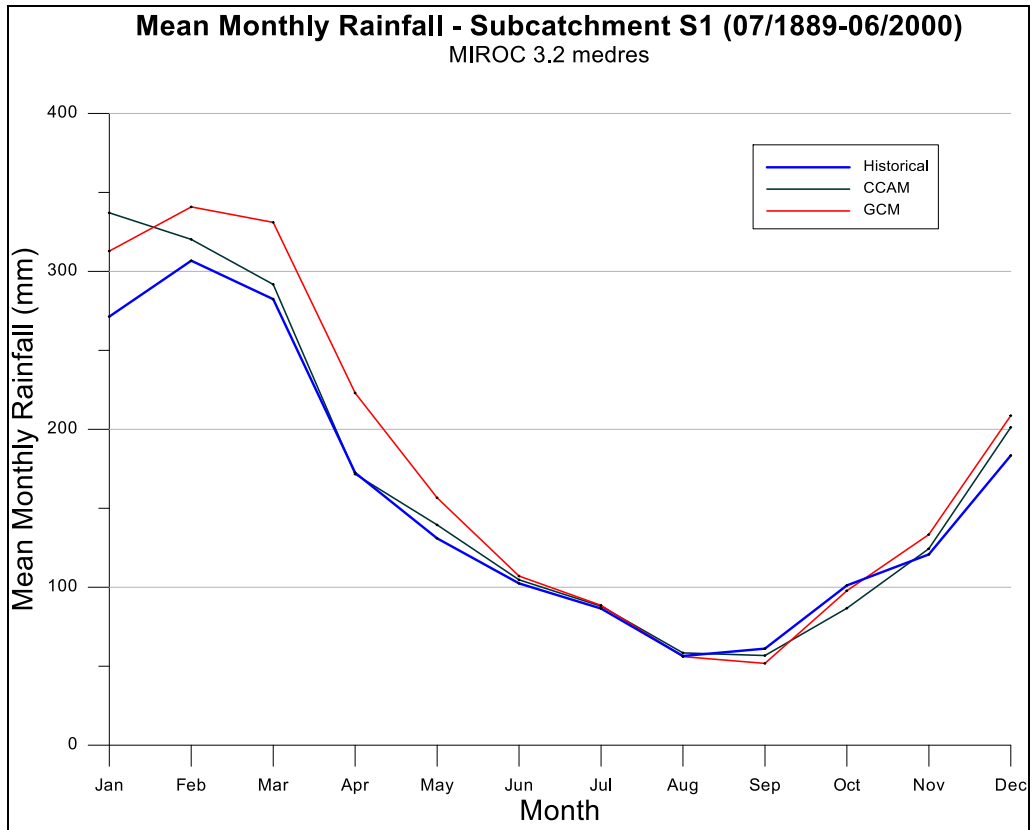


Figure D.40 Mean monthly climate change rainfall – comparison of generation methods for MIROC 3.2 medres (GCM and CCAM) – Subarea S1.

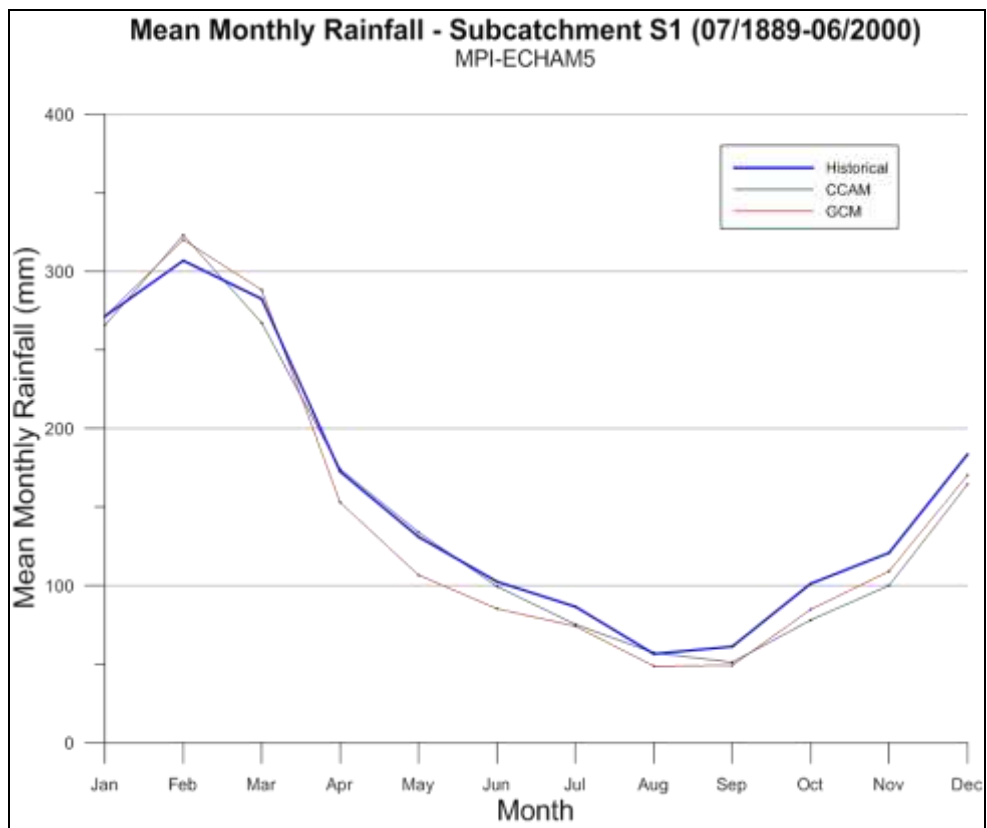


Figure D.41 Mean monthly climate change rainfall – comparison of generation methods for MPI ECHAM5 (GCM and CCAM) – Subarea S1.

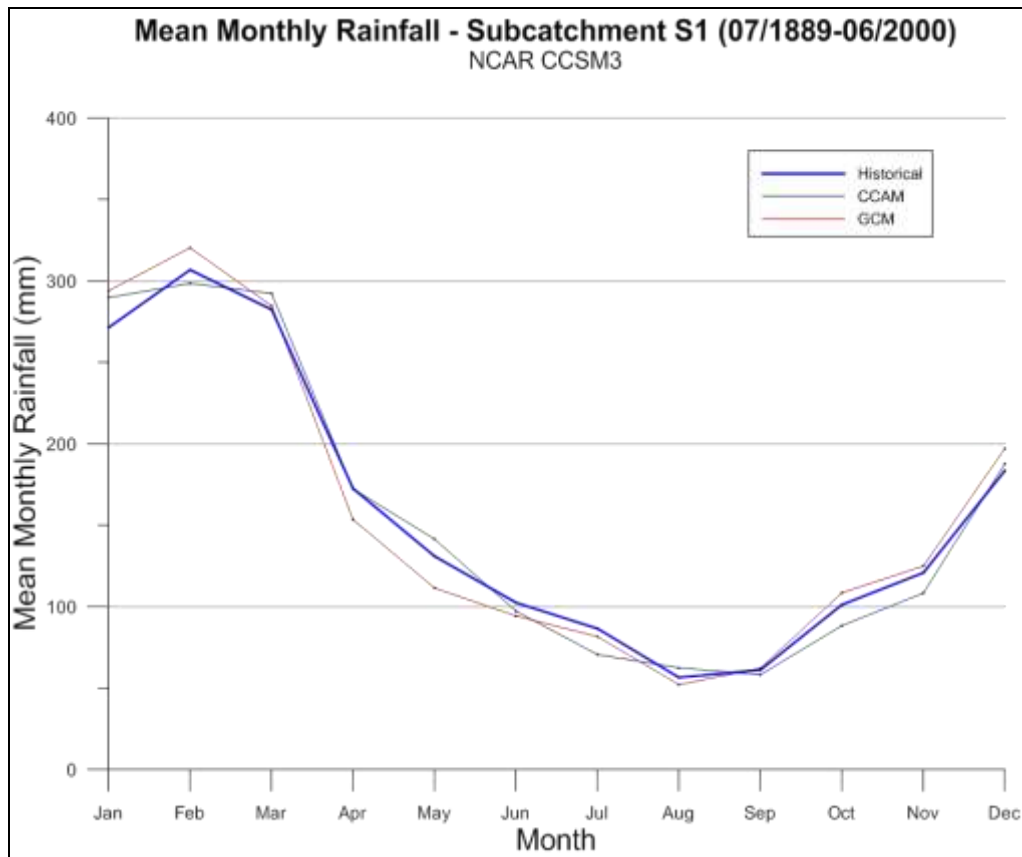


Figure D.42 Mean monthly climate change rainfall – comparison of generation methods for NCAR CCSM3 (GCM and CCAM) – Subarea S1.

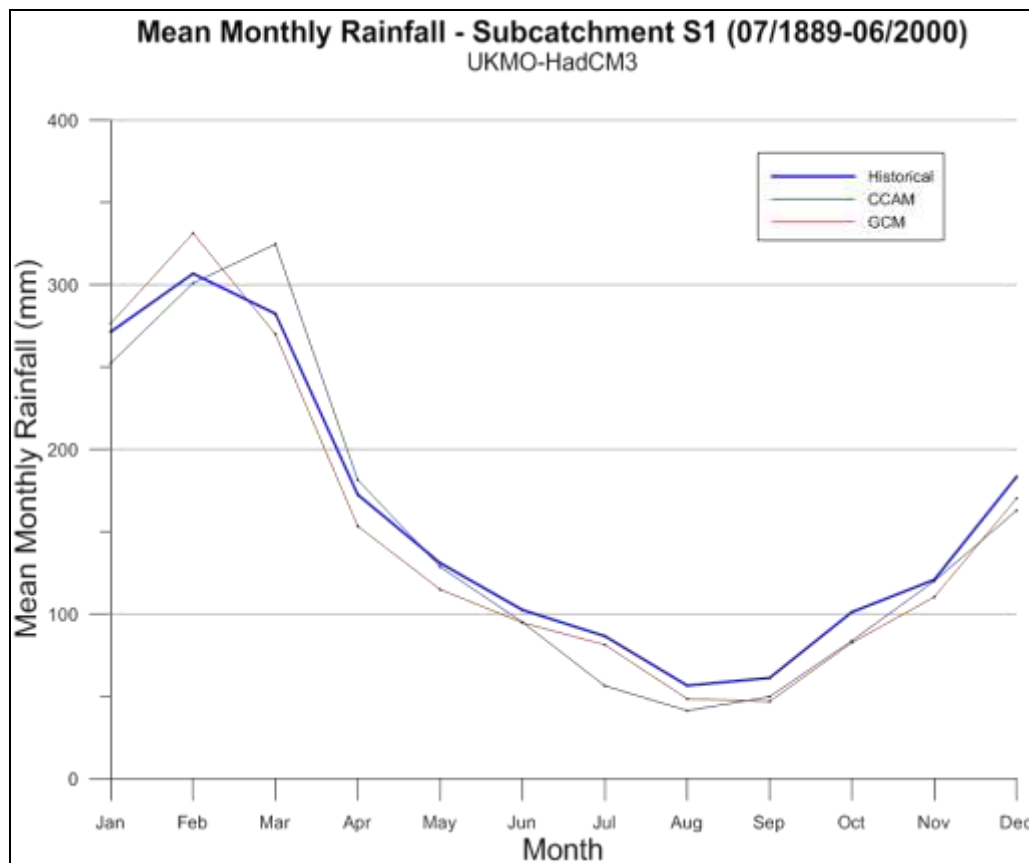


Figure D.43 Mean monthly climate change rainfall – comparison of generation methods for UKMO HadCM3 (GCM and CCAM) – Subarea S1.

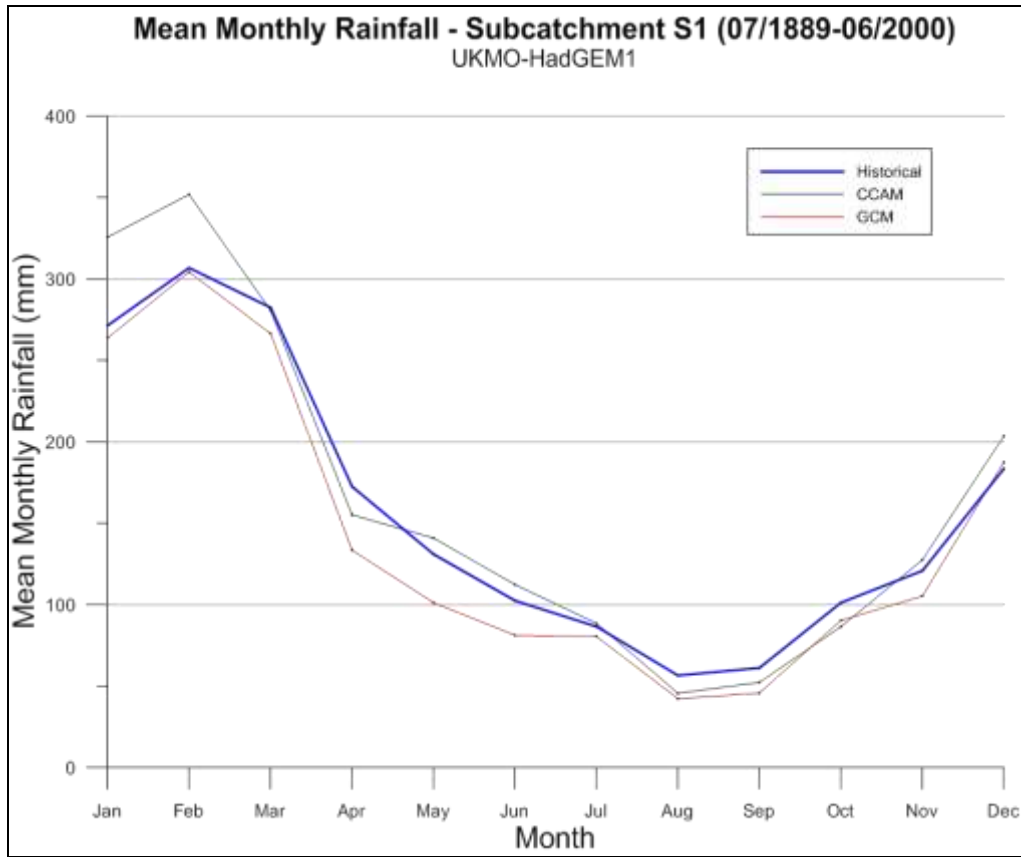


Figure D.44 Mean monthly climate change rainfall – comparison of generation methods for UKMO HadGEM1 (GCM and CCAM) – Subarea S1.

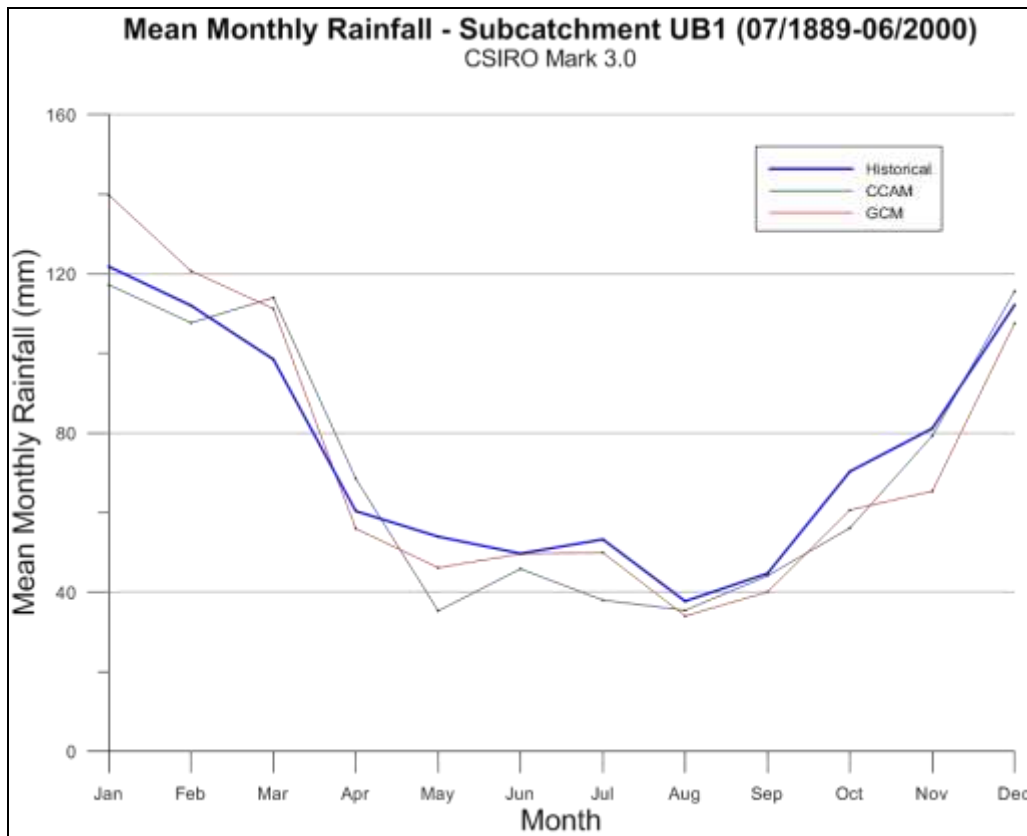


Figure D.45 Mean monthly climate change rainfall – comparison of generation methods for CSIRO Mark 3.0 (GCM and CCAM) – Subarea UB1.

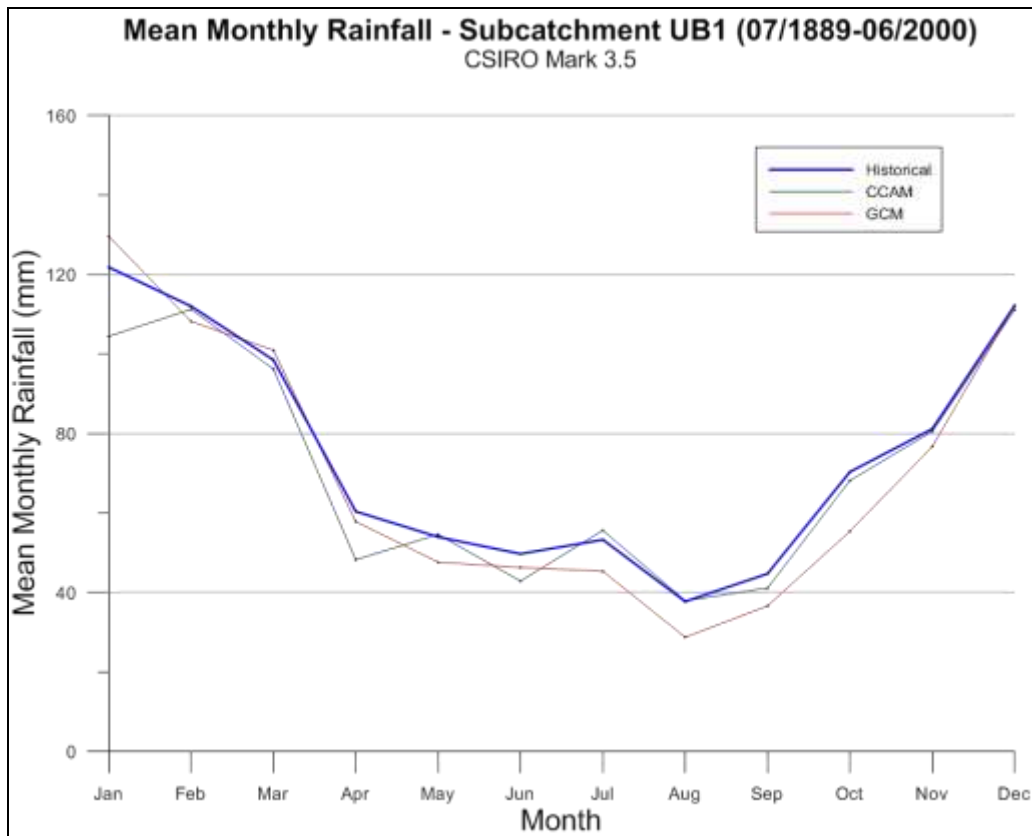


Figure D.46 Mean monthly climate change rainfall – comparison of generation methods for CSIRO Mark 3.5 (GCM and CCAM) – Subarea UB1.

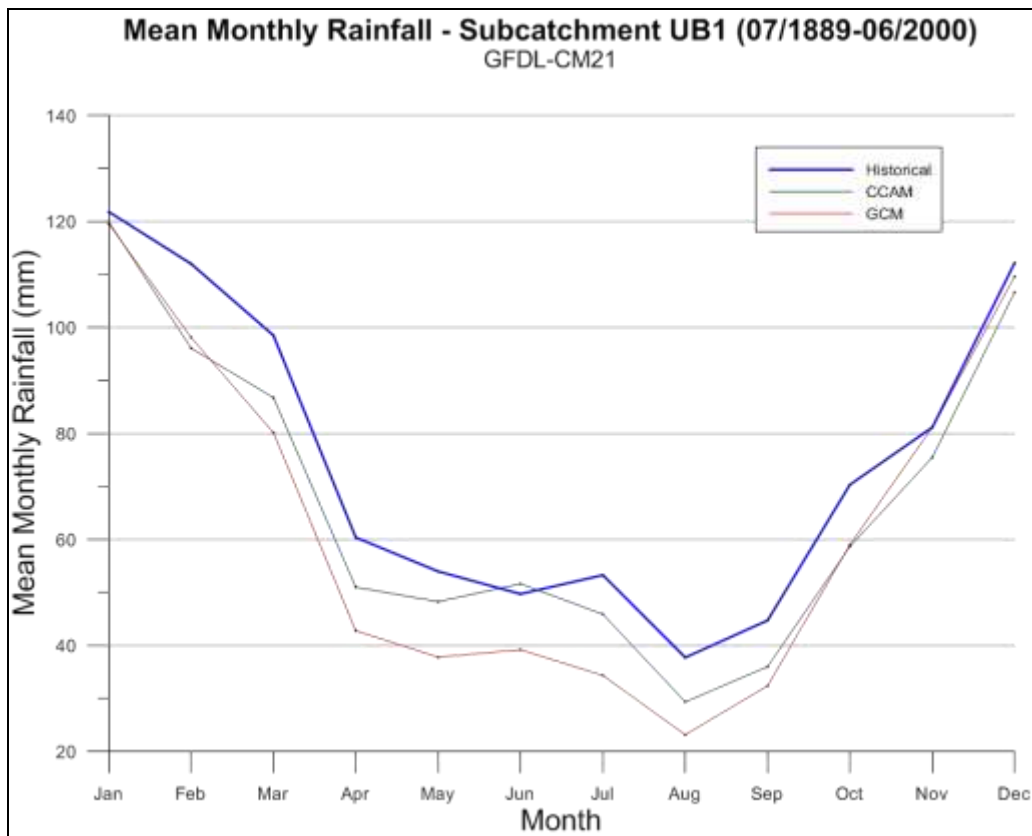


Figure D.47 Mean monthly climate change rainfall – comparison of generation methods for GFDL CM21 (GCM and CCAM) – Subarea UB1.

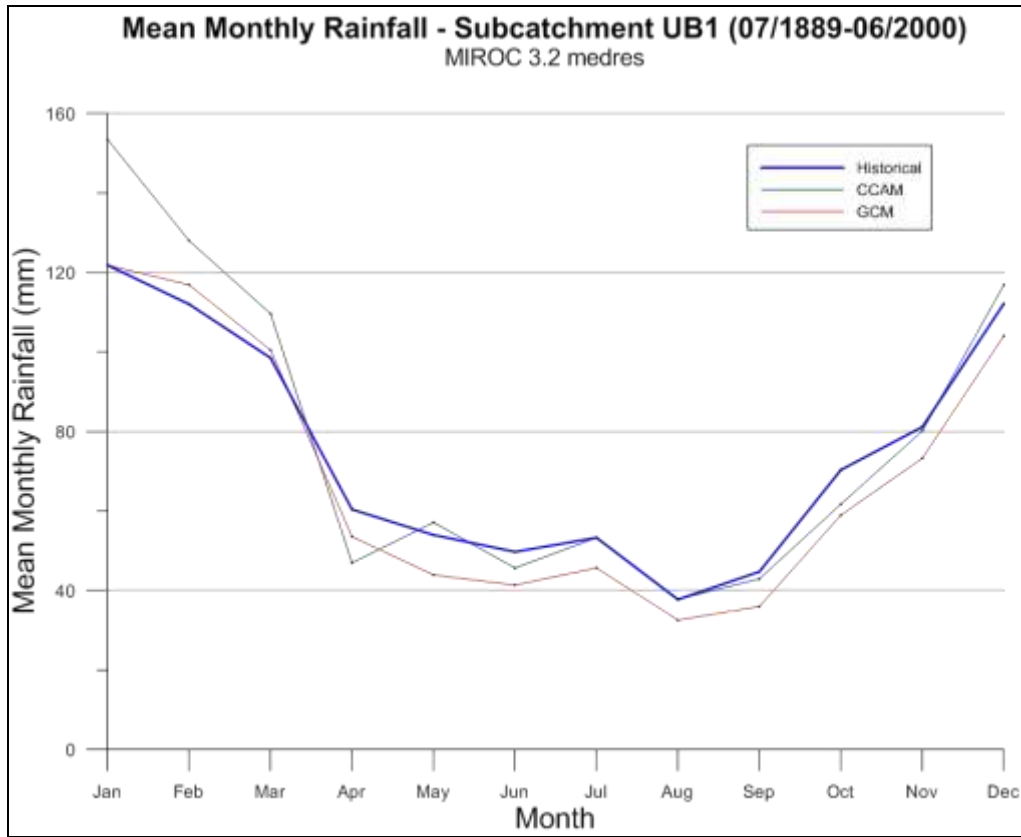


Figure D.48 Mean monthly climate change rainfall – comparison of generation methods for MIROC 3.2 medres (GCM and CCAM) – Subarea UB1.

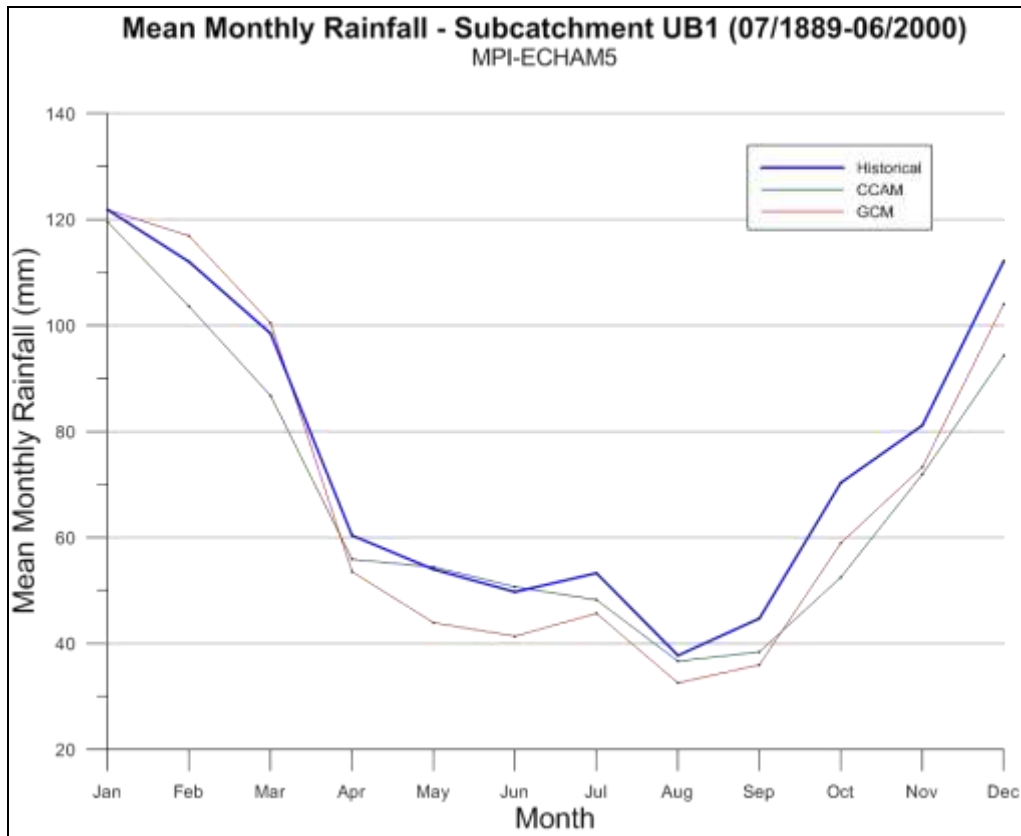


Figure D.49 Mean monthly climate change rainfall – comparison of generation methods for MPI ECHAM5 (GCM and CCAM) – Subarea UB1.

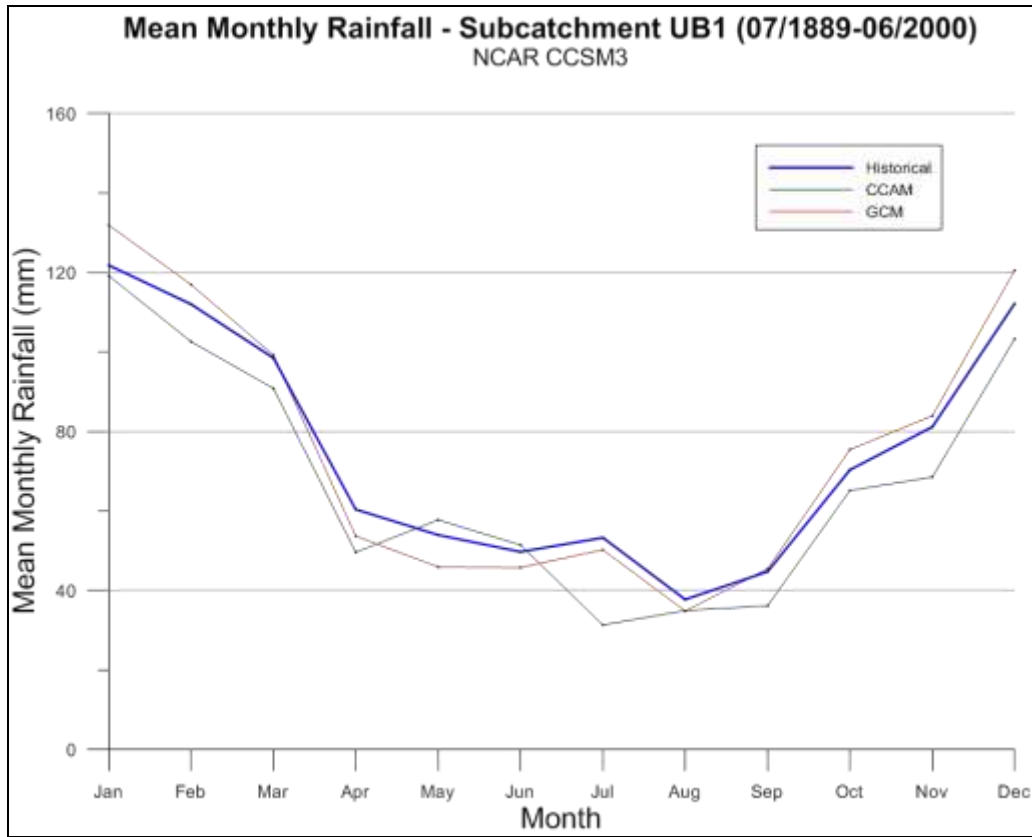


Figure D.50 Mean monthly climate change rainfall – comparison of generation methods for NCAR CCCM3 (GCM and CCAM) – Subarea UB1.

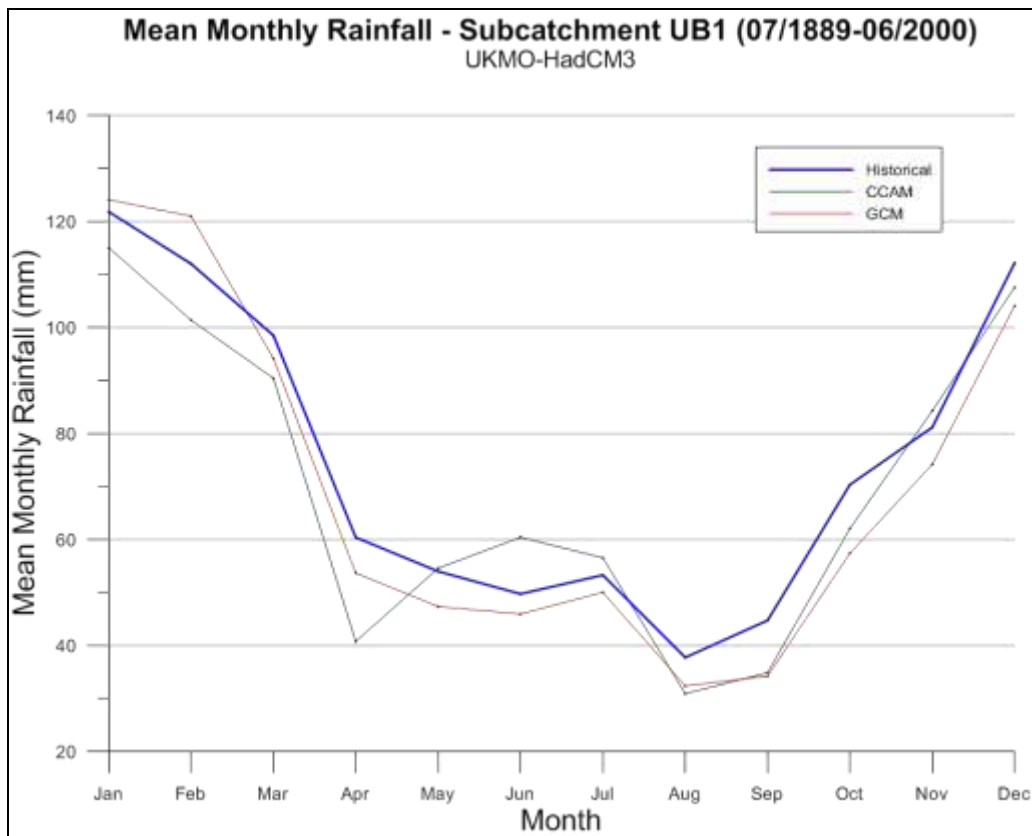


Figure D.51 Mean monthly climate change rainfall – comparison of generation methods for UKMO HadCM3 (GCM and CCAM) – Subarea UB1.

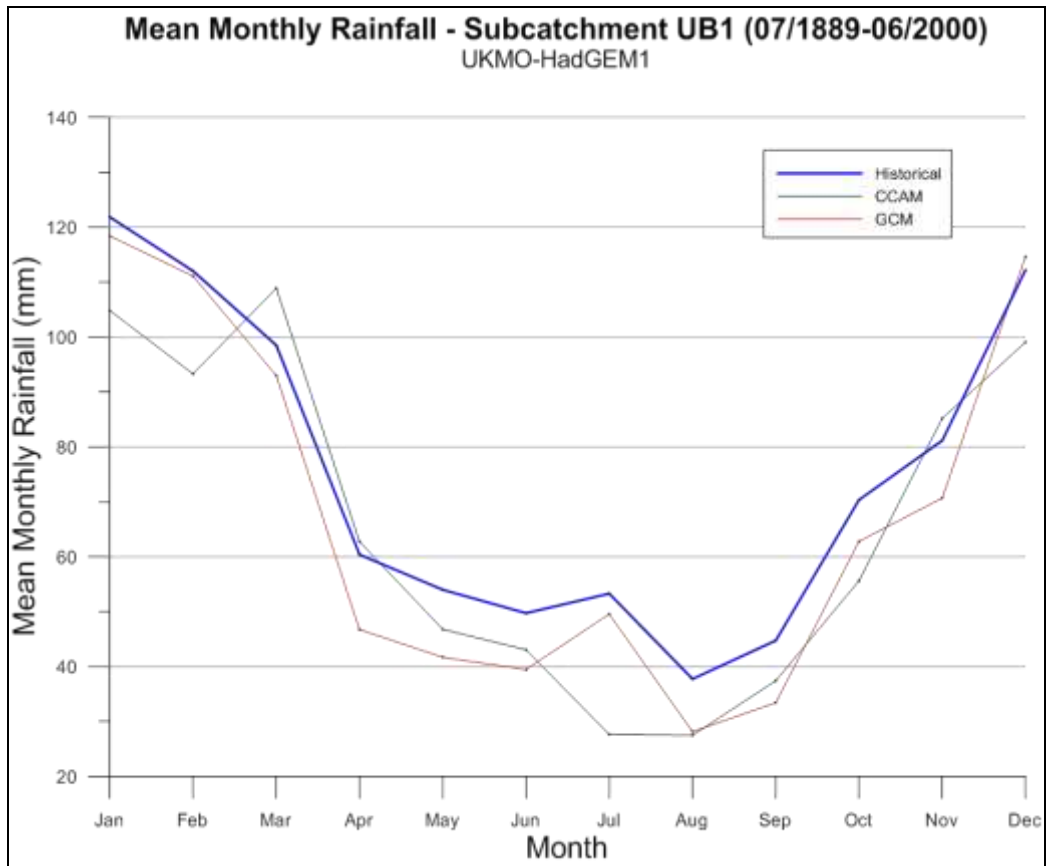


Figure D.52 Mean monthly climate change rainfall – comparison of generation methods for UKMO HadGEM1 (GCM and CCAM) – Subarea UB1.

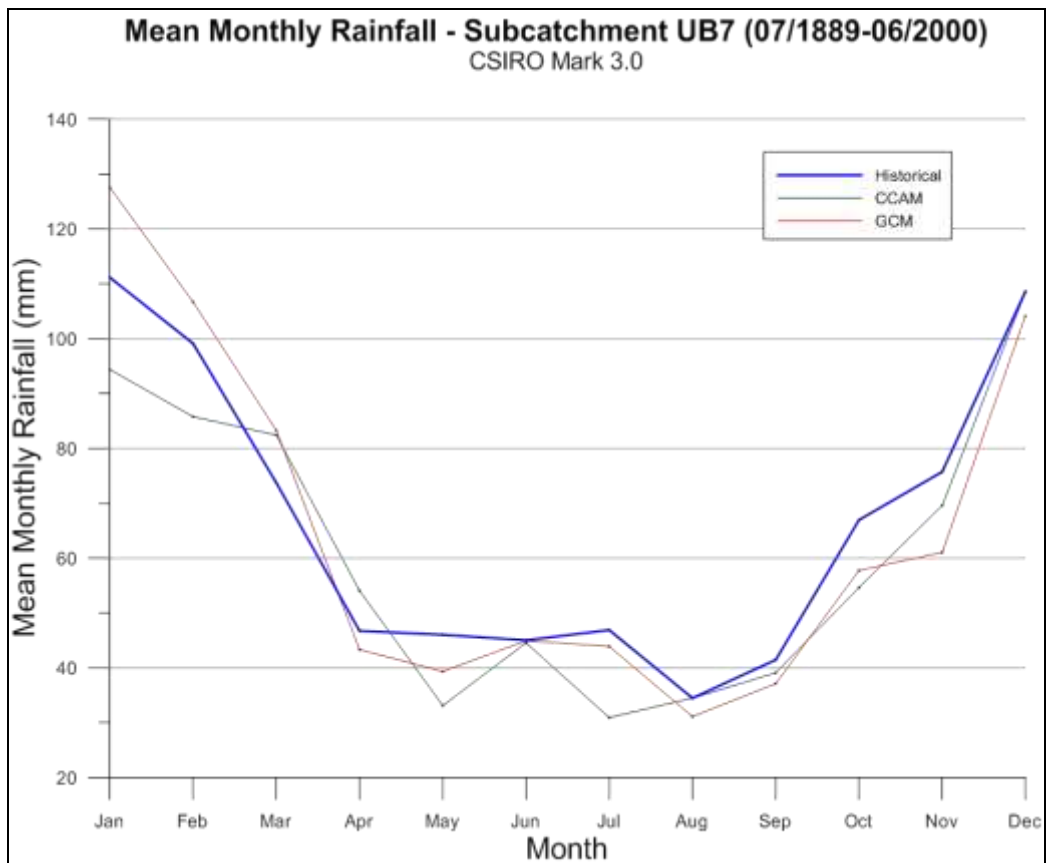


Figure D.53 Mean monthly climate change rainfall – comparison of generation methods for CSIRO Mark 3.0 (GCM and CCAM) – Subarea UB7.

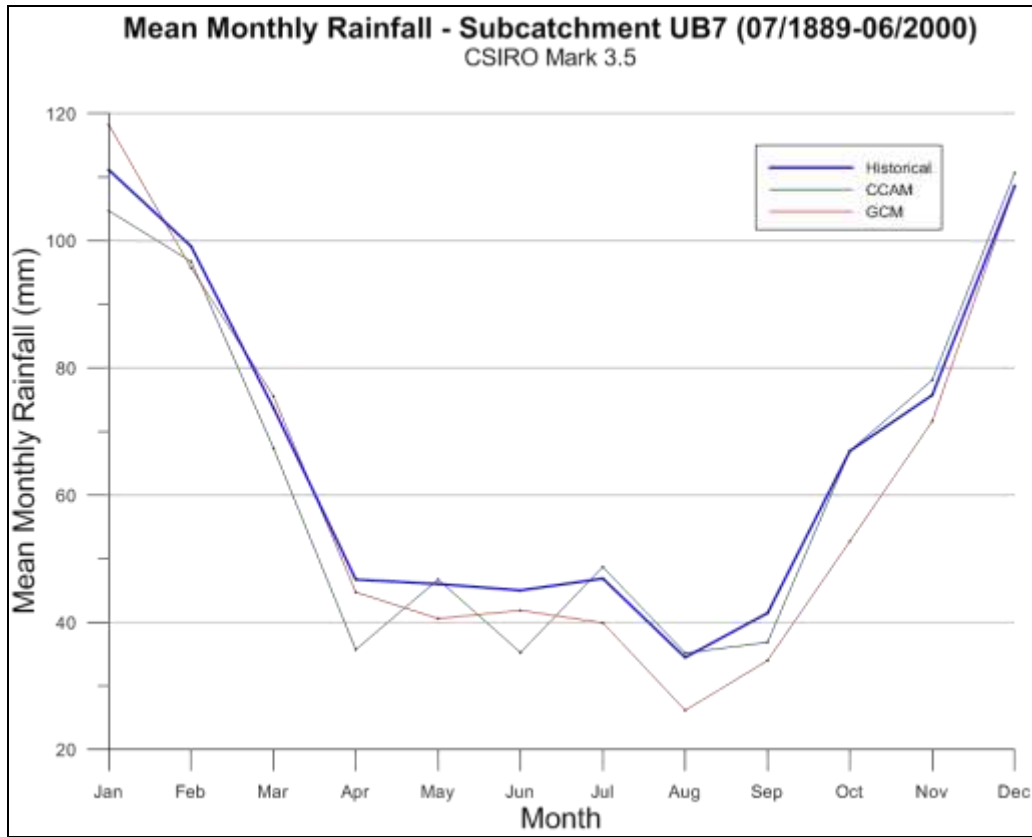


Figure D.54 Mean monthly climate change rainfall – comparison of generation methods for CSIRO Mark 3.5 (GCM and CCAM) – Subarea UB7.

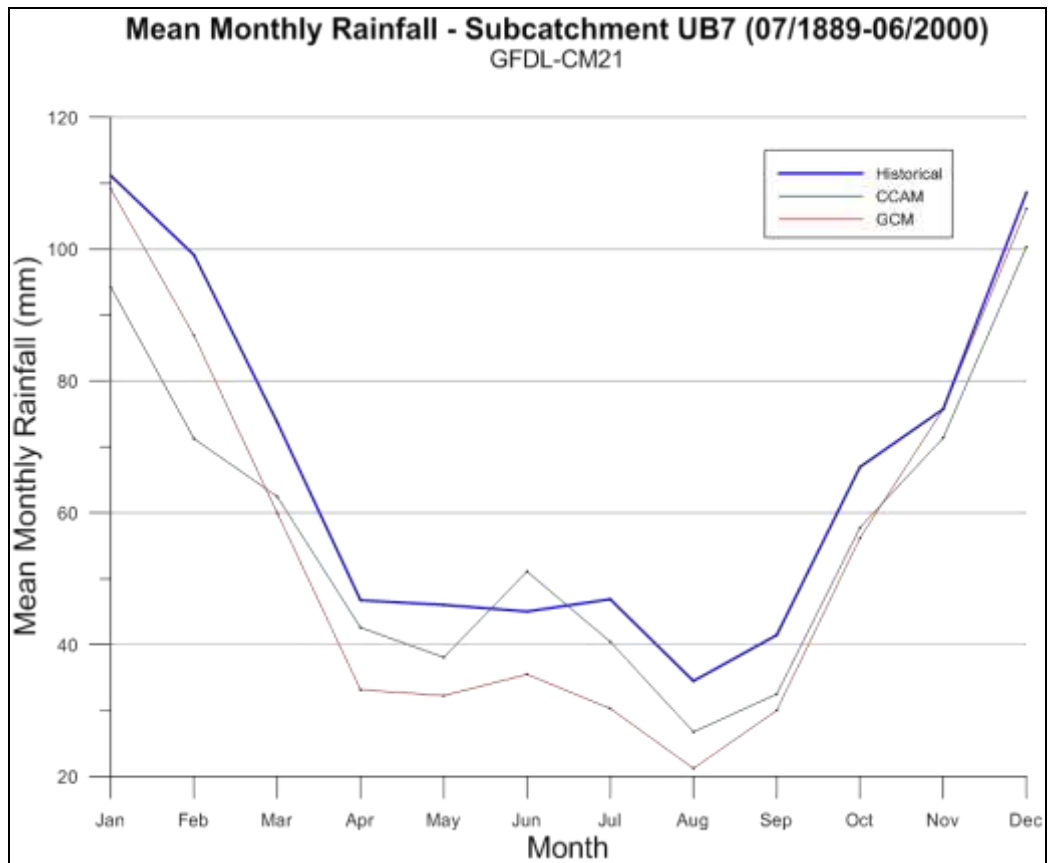


Figure D.55 Mean monthly climate change rainfall – comparison of generation methods for GFDL CM21 (GCM and CCAM) – Subarea UB7.

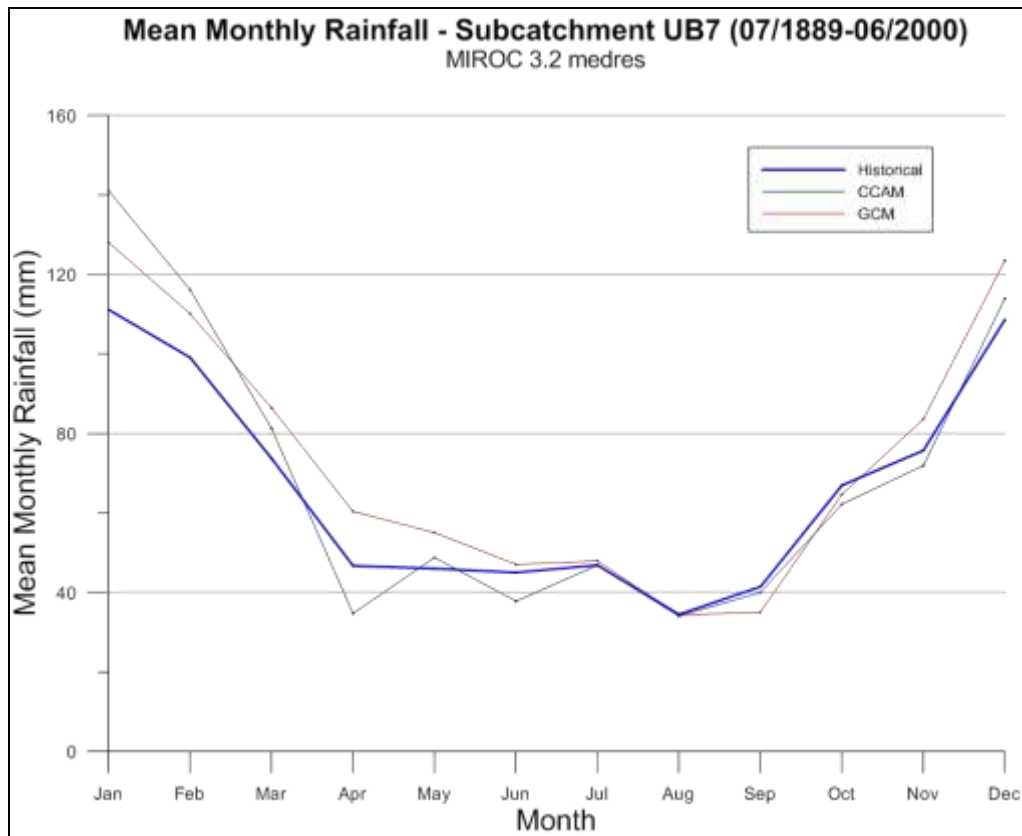


Figure D.56 Mean monthly climate change rainfall – comparison of generation methods for MIROC 3.2 medres (GCM and CCAM) – Subarea UB7.

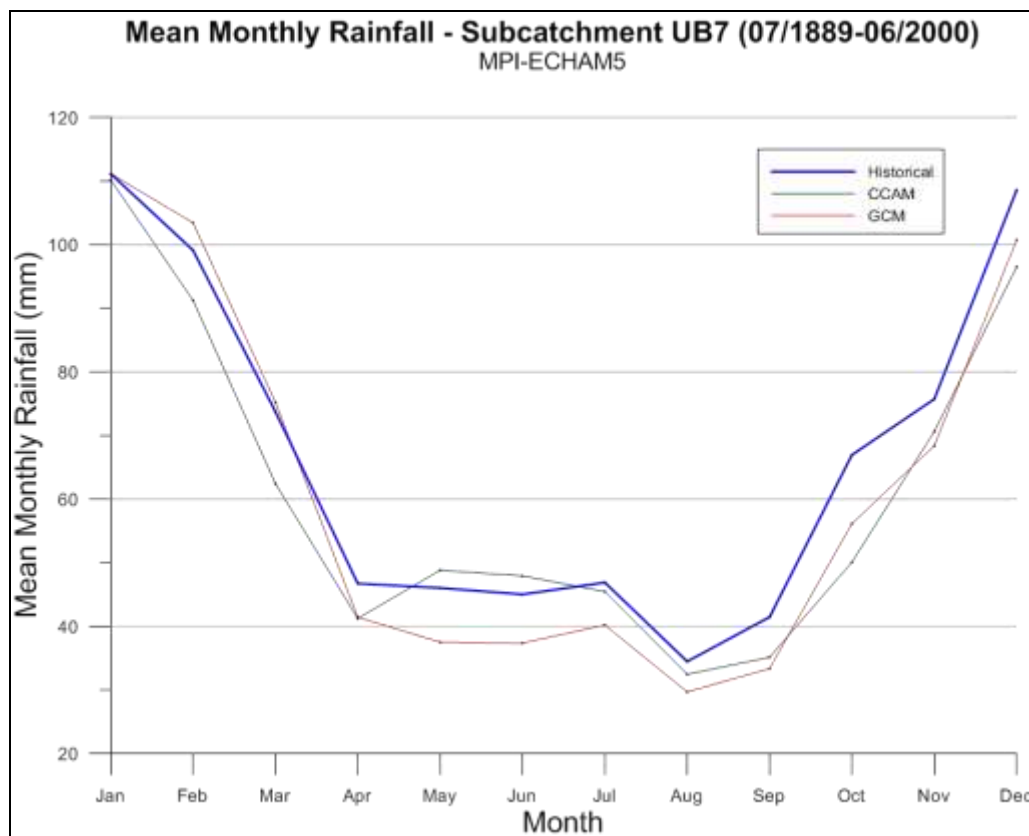


Figure D.57 Mean monthly climate change rainfall – comparison of generation methods for MPI ECHAM5 (GCM and CCAM) – Subarea UB7.

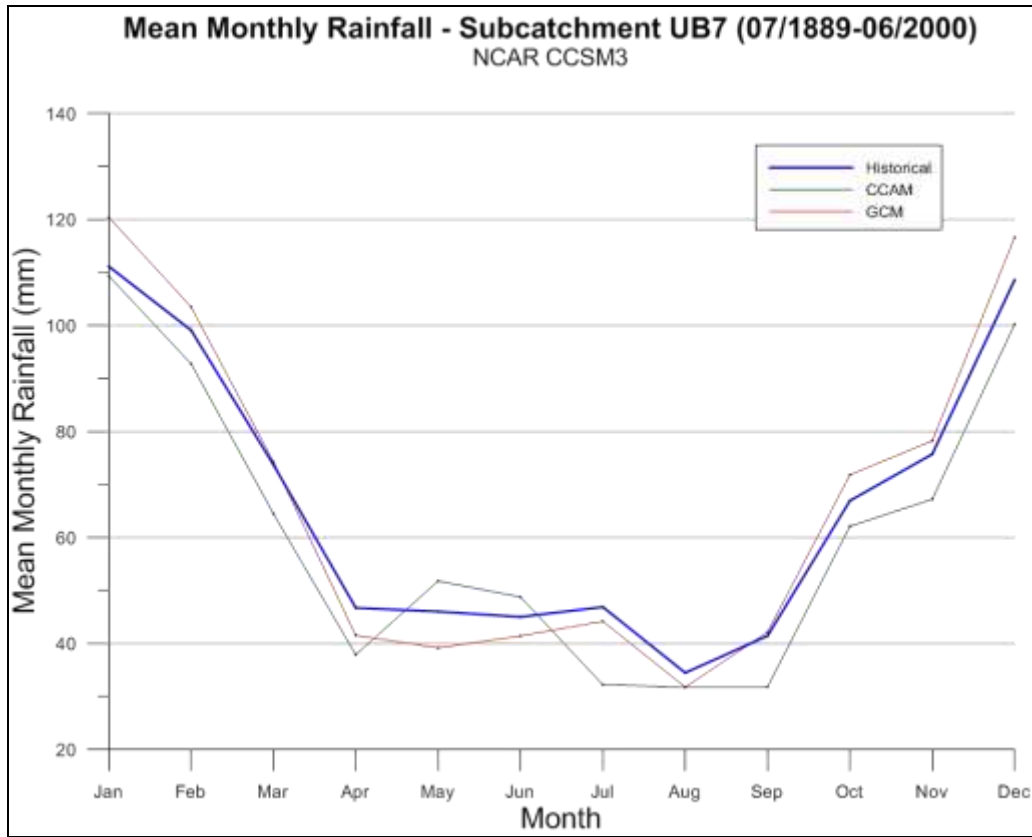


Figure D.58 Mean monthly climate change rainfall – comparison of generation methods for NCAR CCSM3 (GCM and CCAM) – Subarea UB7.

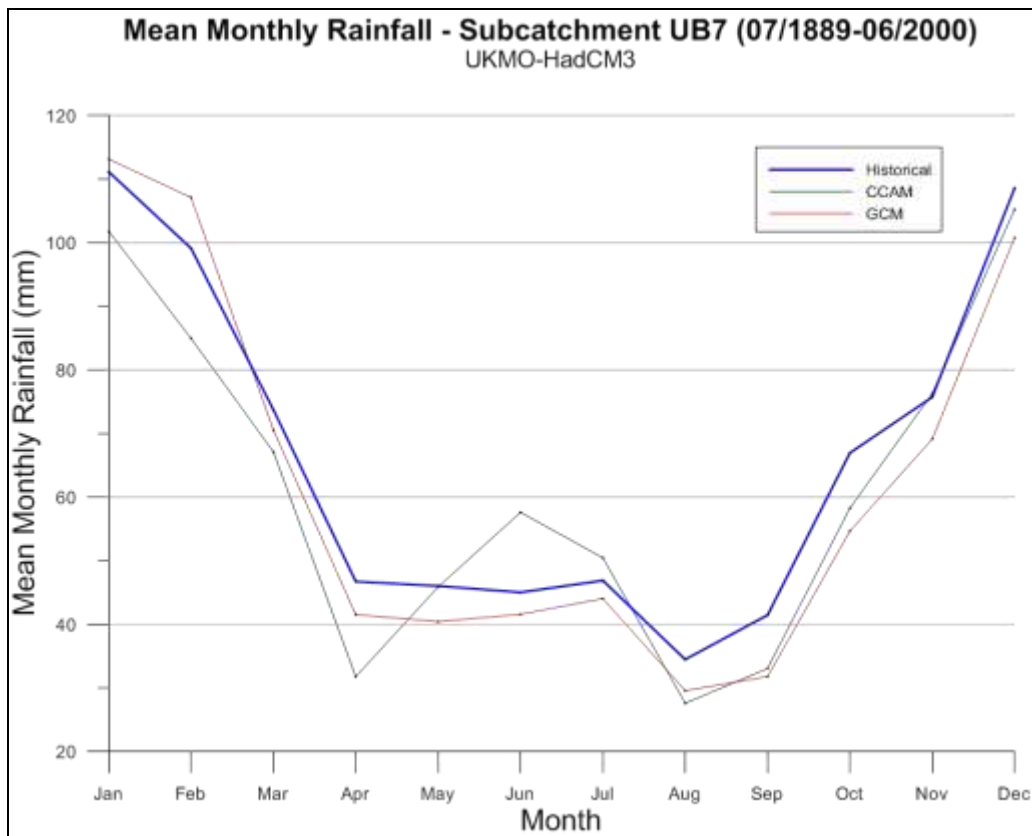


Figure D.59 Mean monthly climate change rainfall – comparison of generation methods for UKMO HadCM3 (GCM and CCAM) – Subarea UB7.

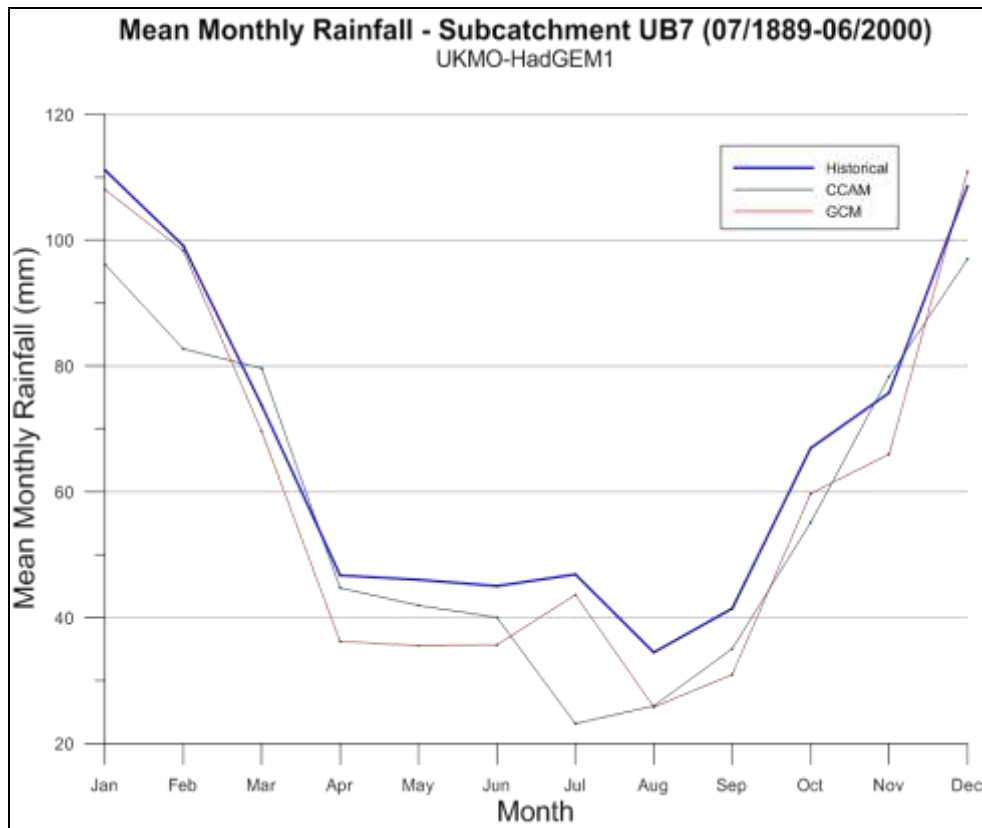


Figure D.60 Mean monthly climate change rainfall – comparison of generation methods for UKMO HadGEM1 (GCM and CCAM) – Subarea UB7.

D.3.2 GCM, CCAM and CCAM PPE1

Table 7.18 Description of Relevant Generation Methods.

Generation Method	Gridsize	Description
GCM	Ranging from 100 to 400km	Global circulation models developed by various research institutes around the world
CCAM	~20km	Original dynamically downscaled models using the Conformal-Cubic Atmospheric Model (CCAM) – downscaled to 20km
CCAM PPE1	~ 8km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 8km
CCAM PPE1	~20km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 20km

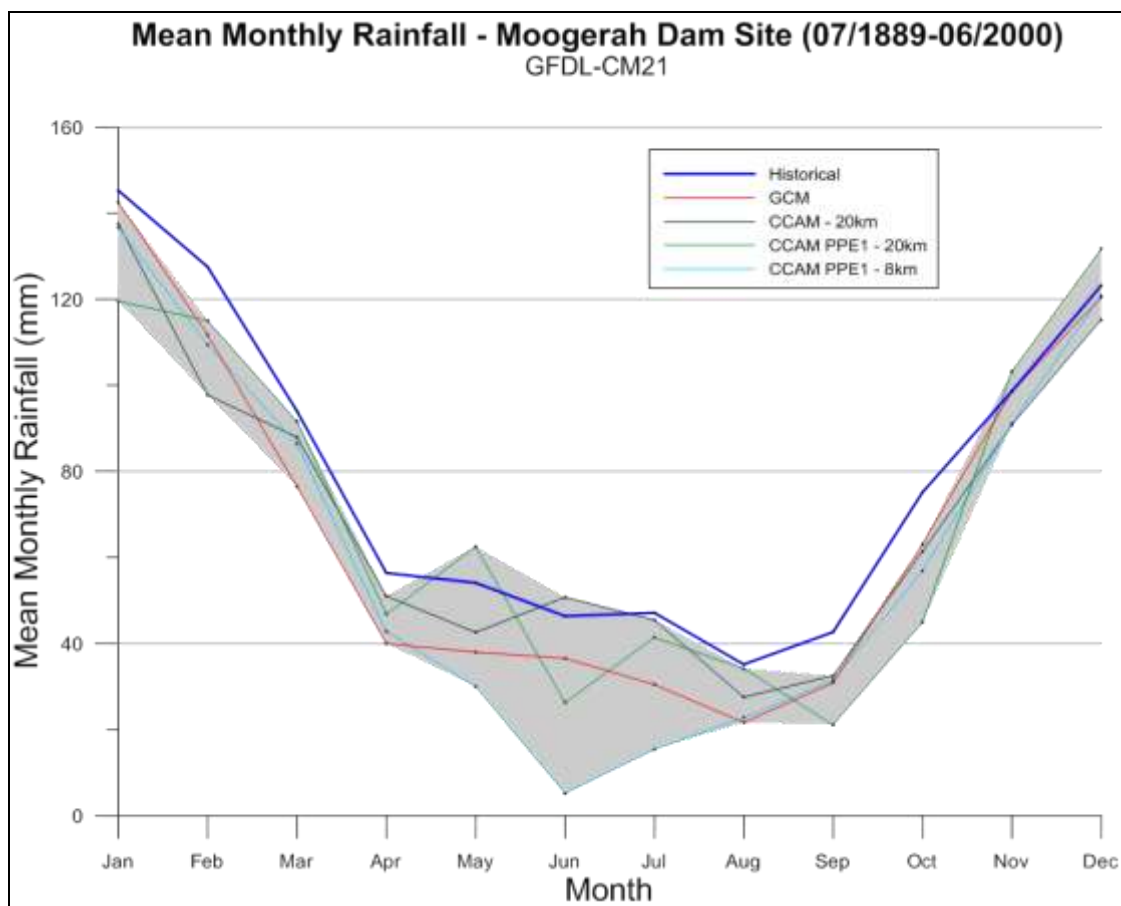


Figure D.61 Mean monthly climate change rainfall – comparison of generation methods for GFDL CM21 (GCM, CCAM and CCAM PPE1) – Subarea B1 (Moogerah Dam Site).

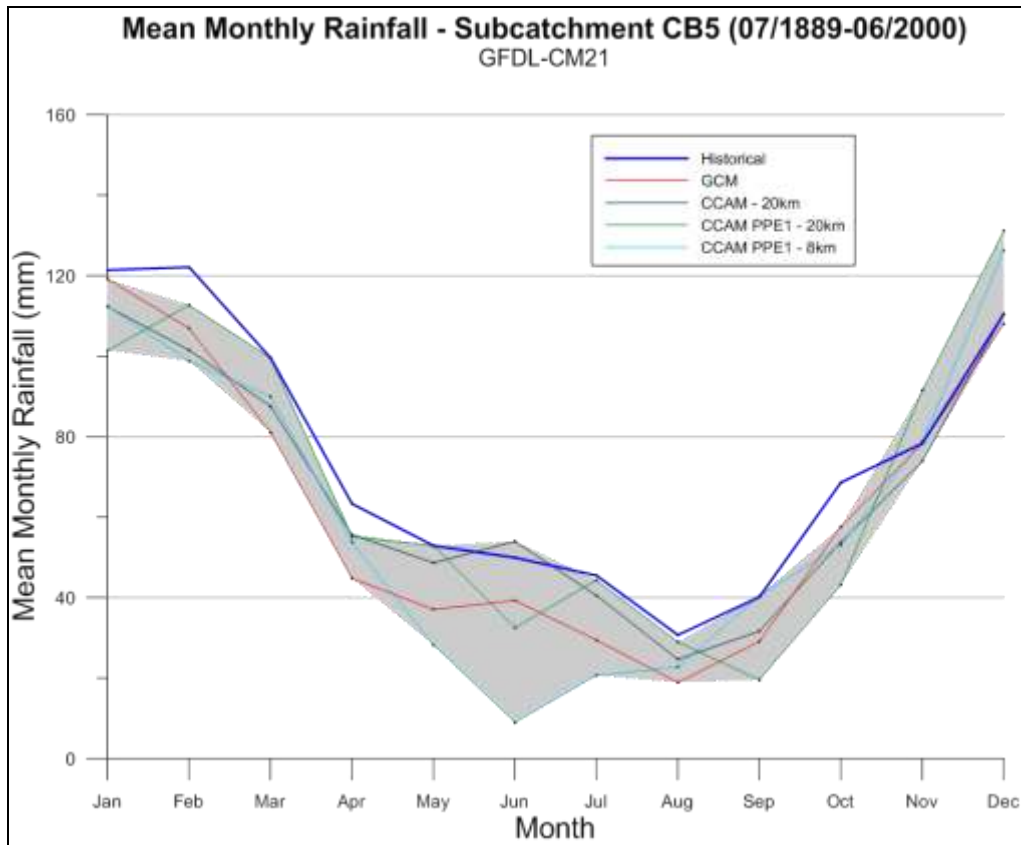


Figure D.62 Mean monthly climate change rainfall – comparison of generation methods for GFDL CM21 (GCM, CCAM and CCAM PPE1) – Subarea CB5.

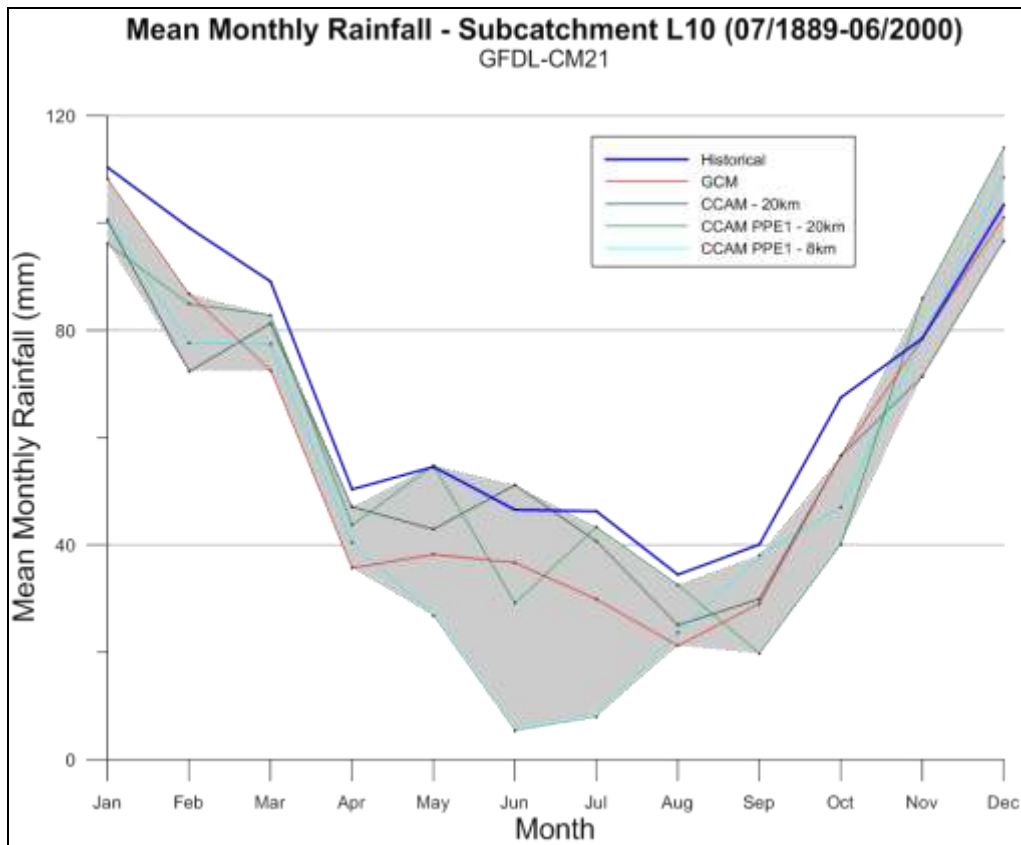


Figure D.63 Mean monthly climate change rainfall – comparison of generation methods for GFDL CM21 (GCM, CCAM and CCAM PPE1) – Subarea L10.

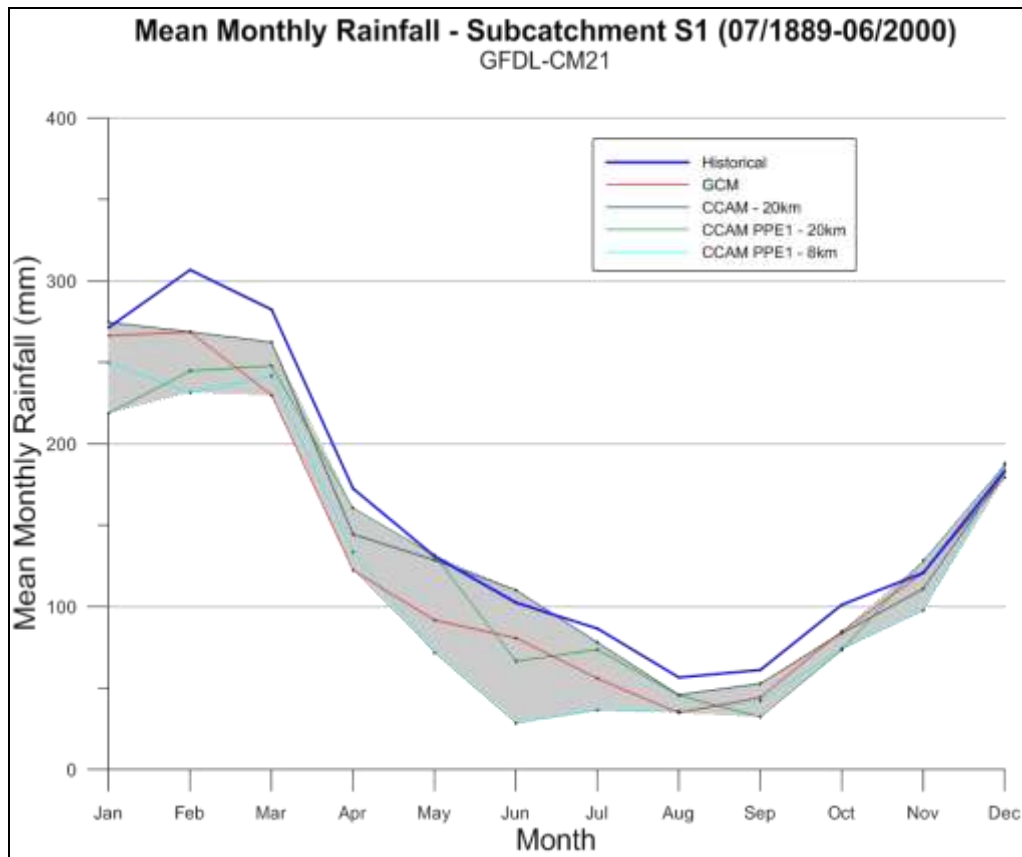


Figure D.64 Mean monthly climate change rainfall – comparison of generation methods for GFDL CM21 (GCM, CCAM and CCAM PPE1) – Subarea S1.

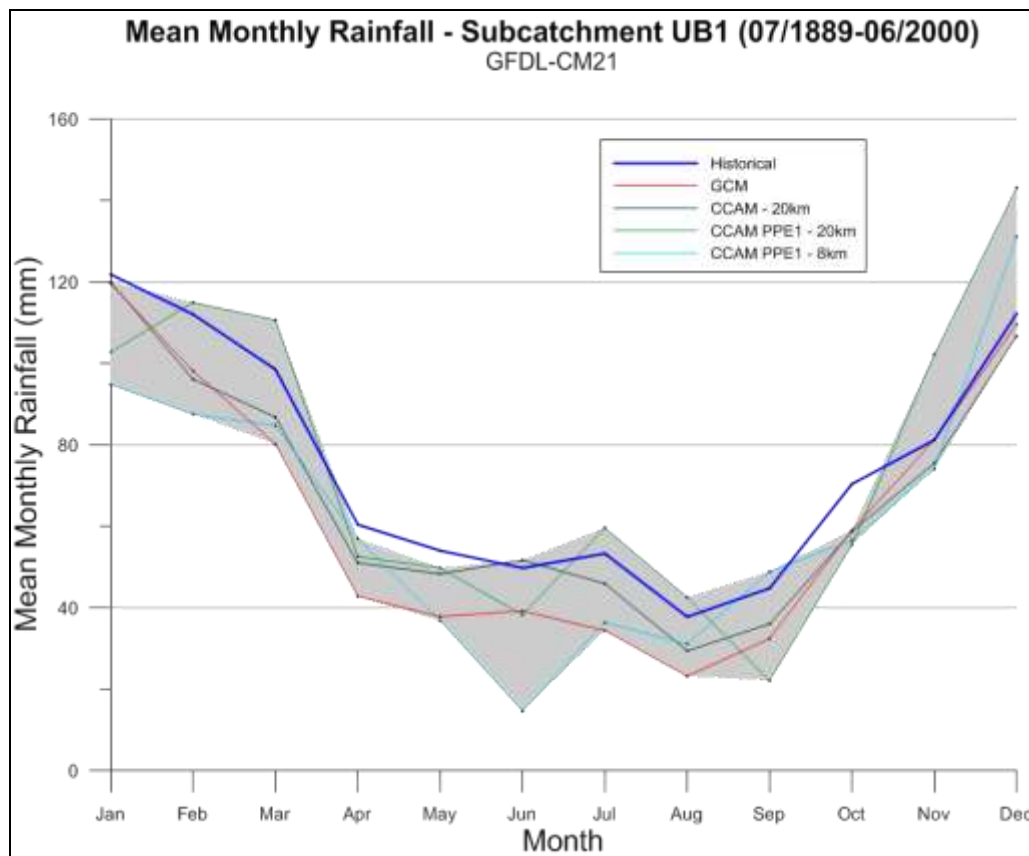


Figure D.65 Mean monthly climate change rainfall – comparison of generation methods for GFDL CM21 (GCM, CCAM and CCAM PPE1) – Subarea UB1.

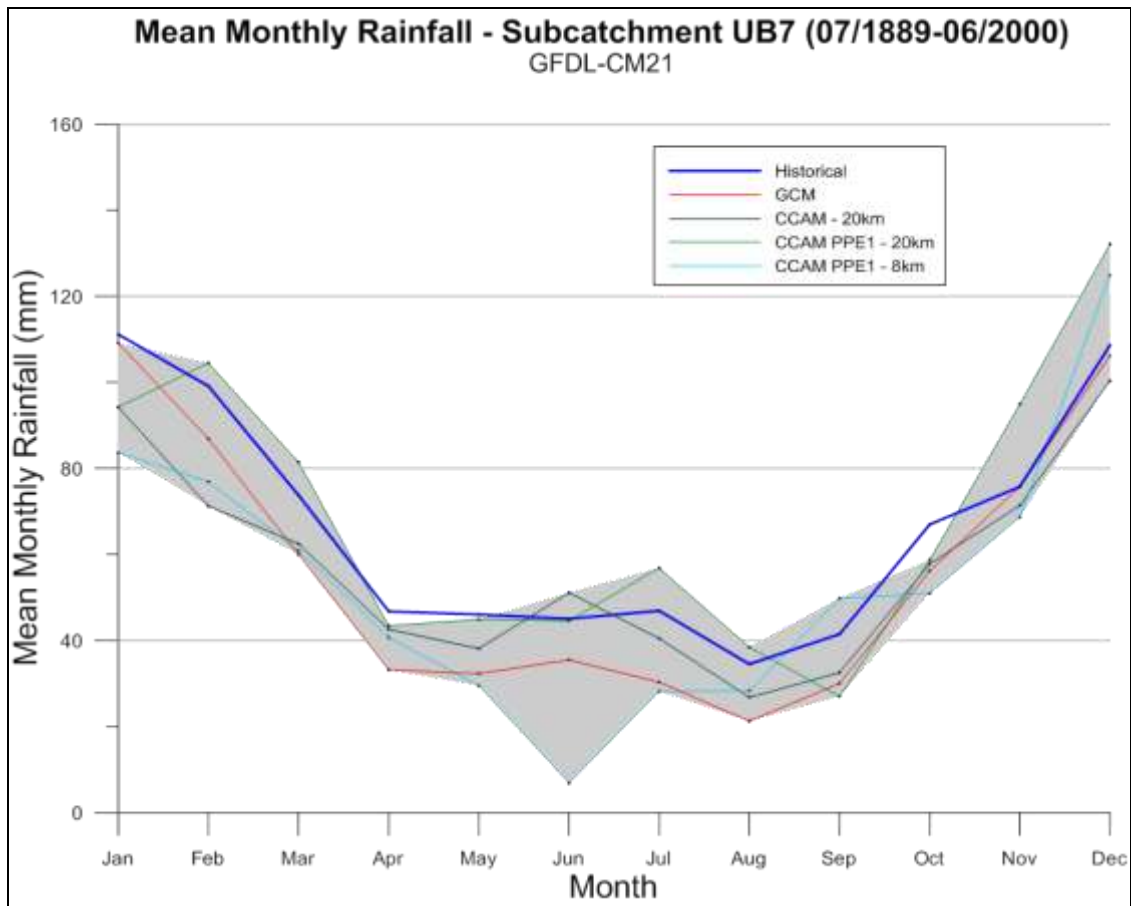


Figure D.66 Mean monthly climate change rainfall – comparison of generation methods for GFDL CM21 (GCM, CCAM and CCAM PPE1) – Subarea UB7.

APPENDIX E Climate Change Model Input Data – Evaporation

E.1 Global Circulation Model Method

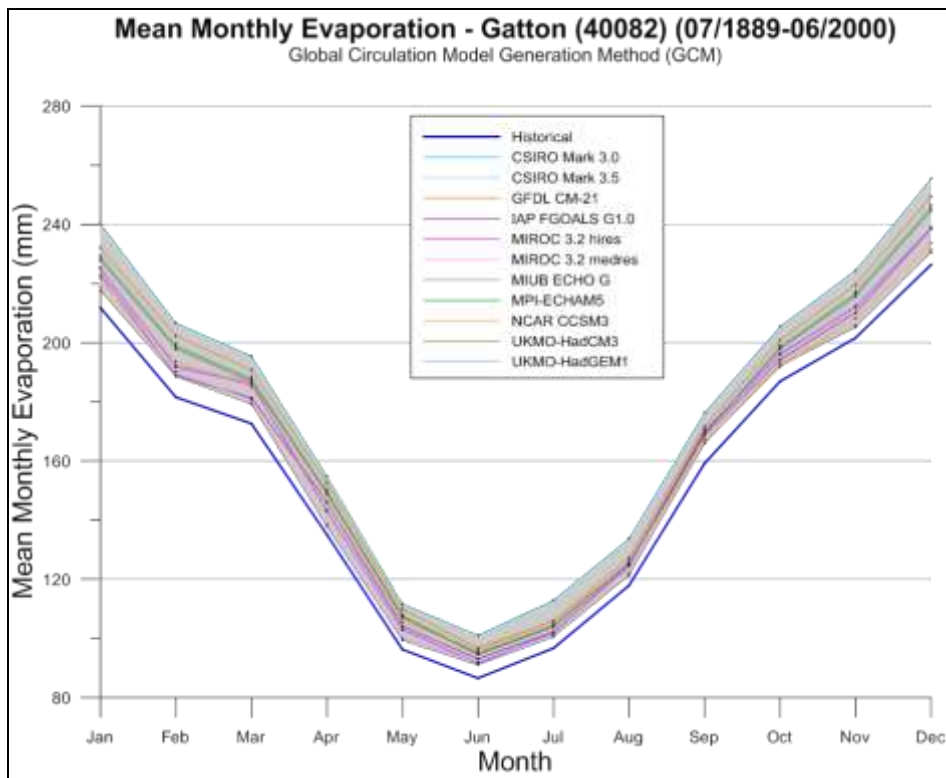


Figure E.1 Mean monthly climate change evaporation – GCM – Gattton (40082).

E.2 Downscaled Generation Method

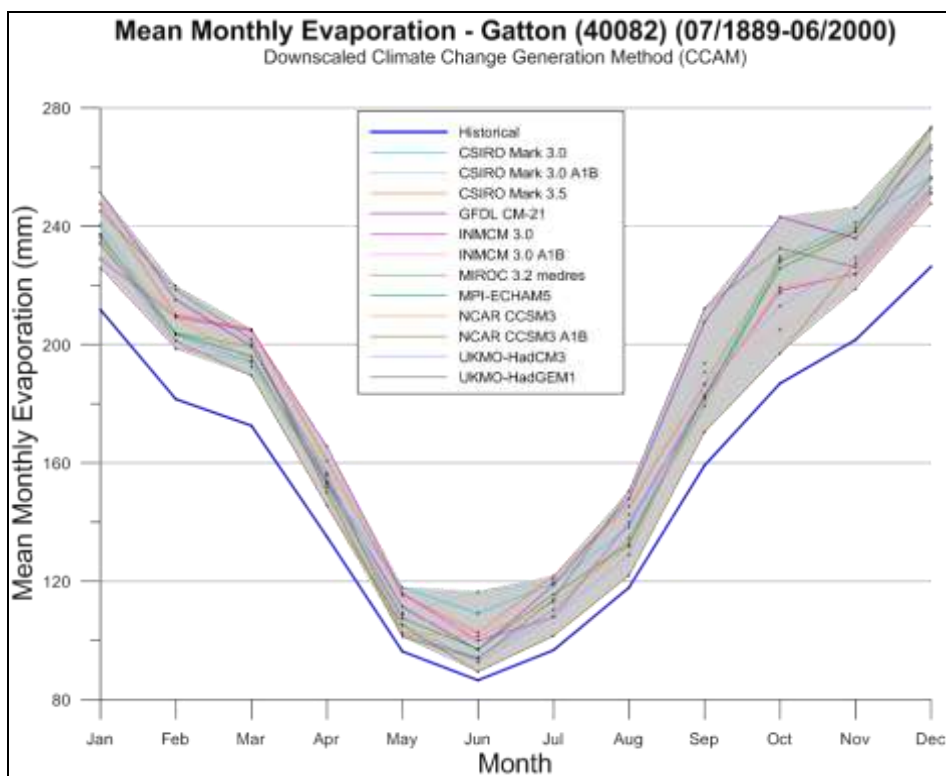


Figure E.2 Mean monthly climate change evaporation – CCAM – Gattton (40082).

E.3 Comparison of Generation Methods

E.3.1 GCM and CCAM

Table 7.19 Description of Relevant Generation Methods

Generation Method	Gridsize	Description
GCM	Ranging from 100 to 400km	Global circulation models developed by various research institutes around the world
CCAM	~20km	Original dynamically downscaled models using the Conformal-Cubic Atmospheric Model (CCAM) – downscaled to 20km

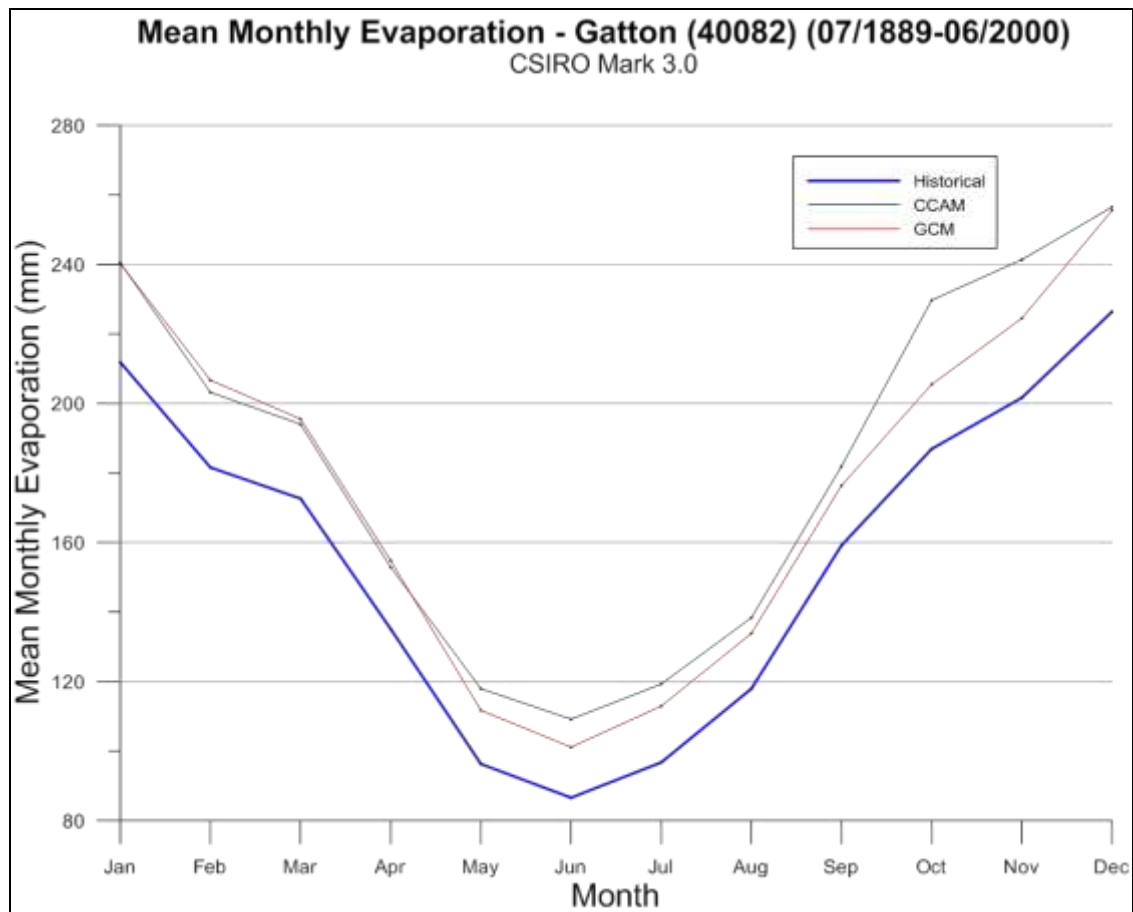


Figure E.3 Mean monthly climate change evaporation – comparison of generation methods for CSIRO Mark 3.0 (GCM and CCAM) – Gatton (40082).

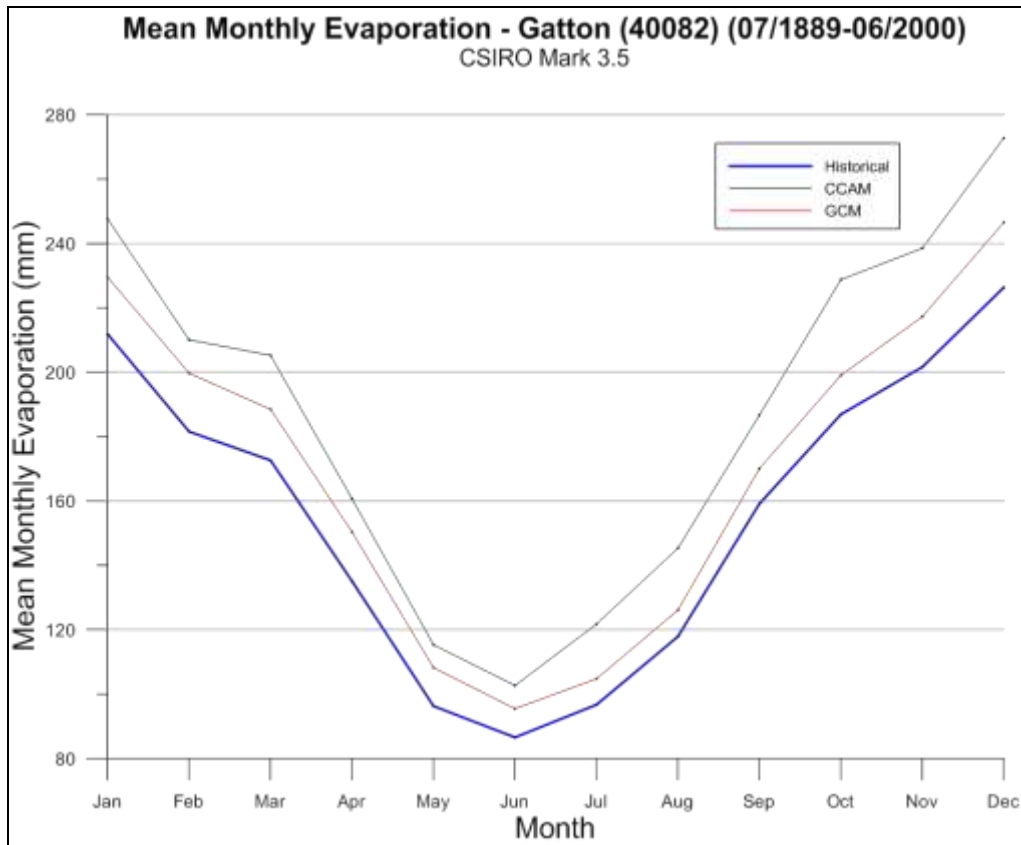


Figure E.4 Mean monthly climate change evaporation – comparison of generation methods for CSIRO Mark 3.5 (GCM and CCAM) – Gattton (40082).

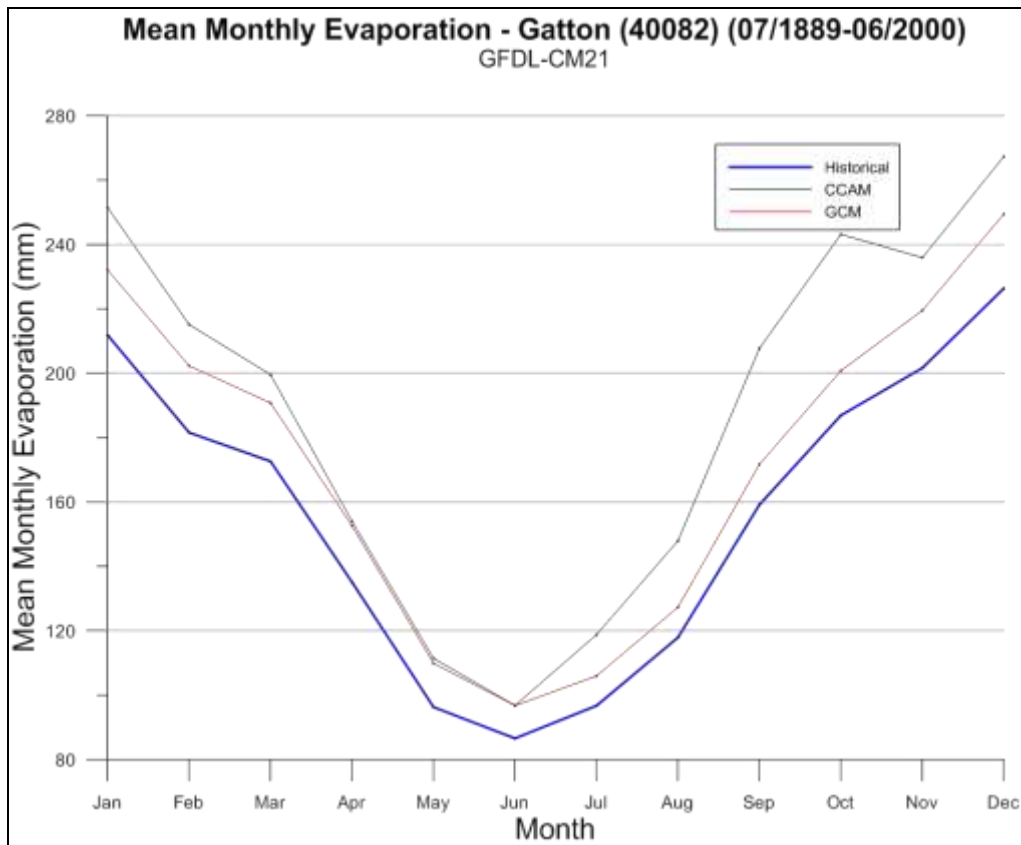


Figure E.5 Mean monthly climate change evaporation – comparison of generation methods for GFDL CM21 (GCM and CCAM) – Gattton (40082).

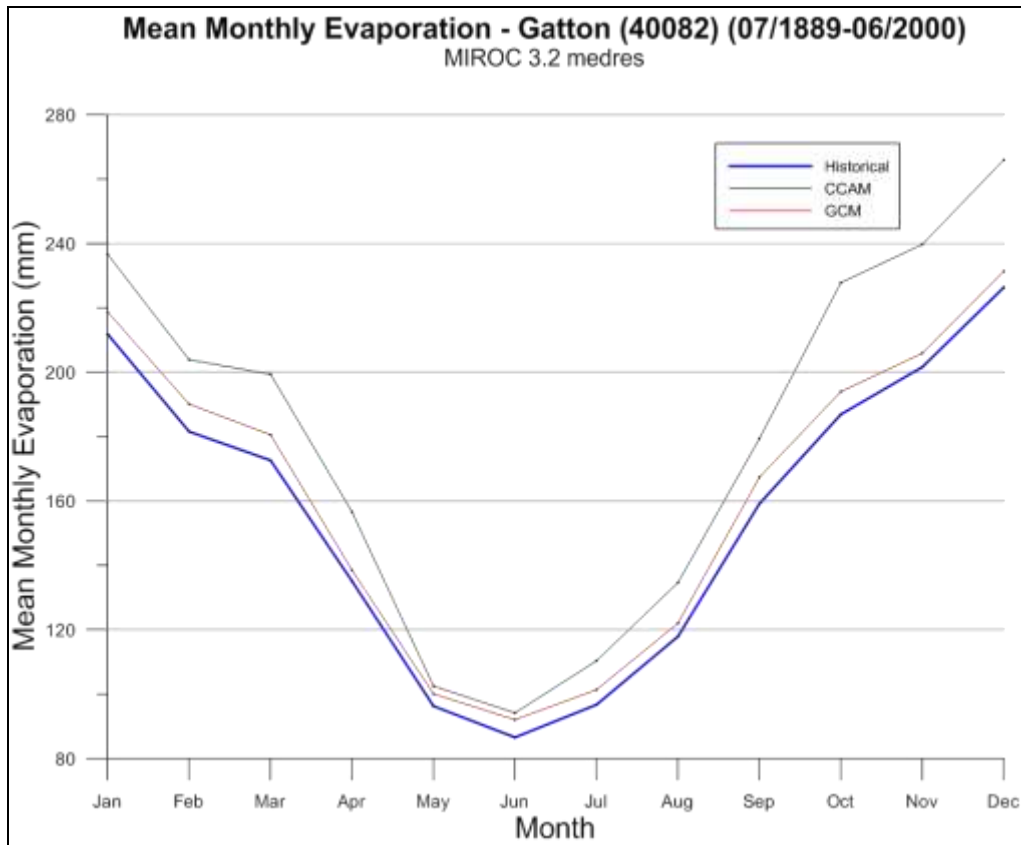


Figure E.6 Mean monthly climate change evaporation – comparison of generation methods for MIROC 3.2 medres (GCM and CCAM) – Gatton (40082).

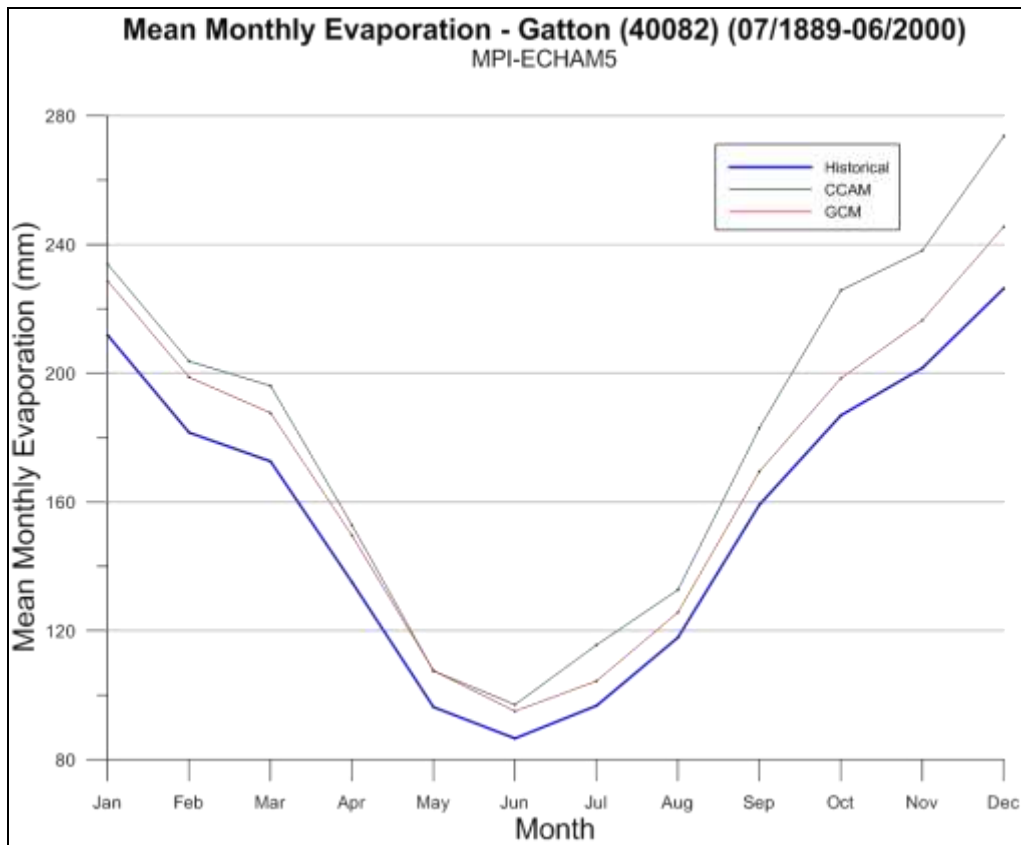


Figure E.7 Mean monthly climate change evaporation – comparison of generation methods for MPI ECHAM5 (GCM and CCAM) – Gatton (40082).

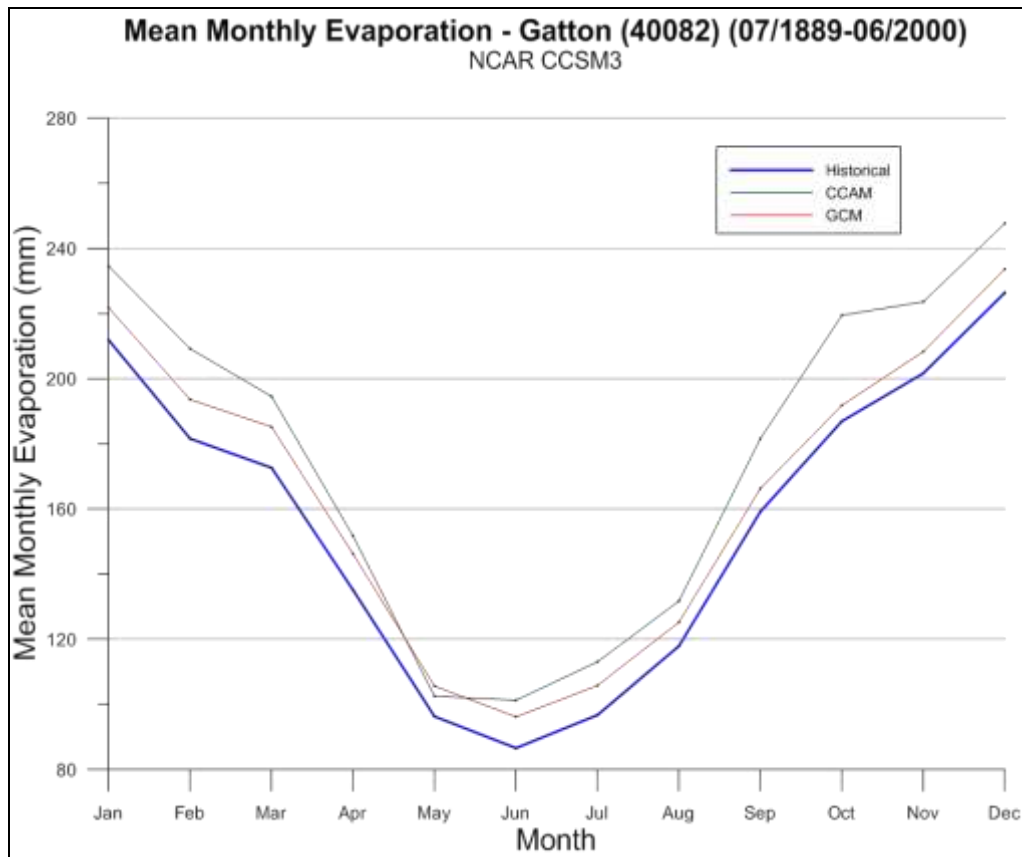


Figure E.8 Mean monthly climate change evaporation – comparison of generation methods for NCAR CCSM3 (GCM and CCAM) – Gatton (40082).

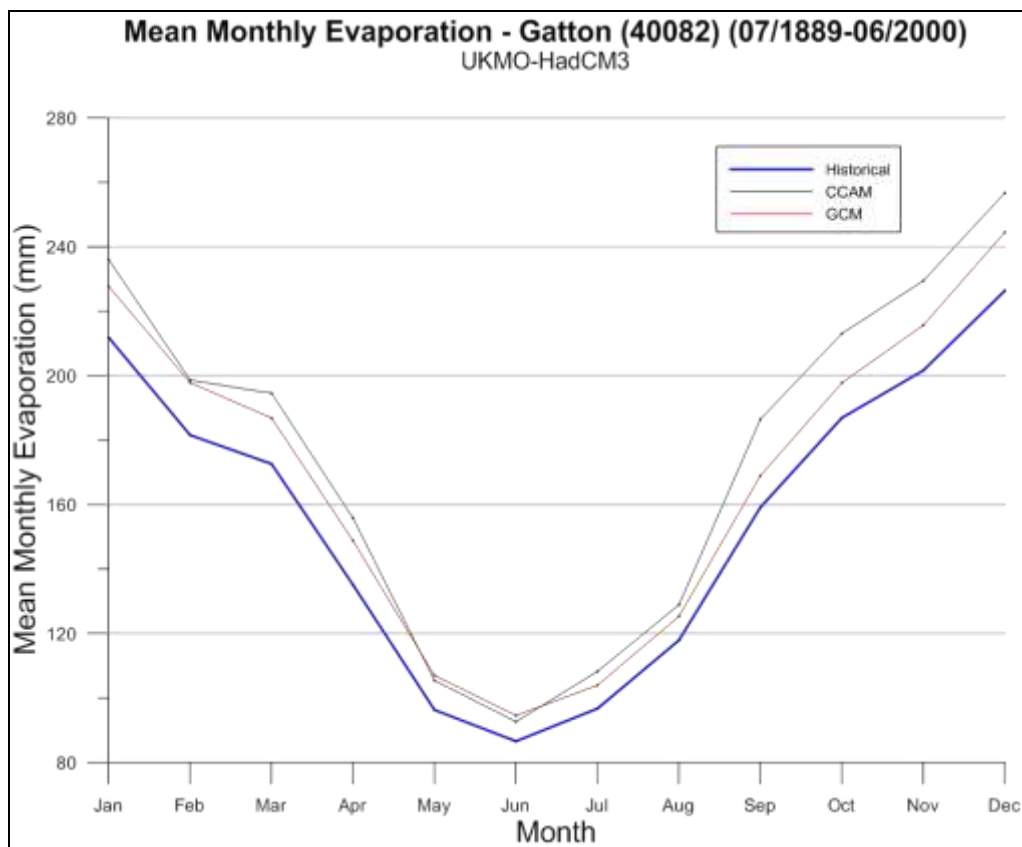


Figure E.9 Mean monthly climate change evaporation – comparison of generation methods for UKMO HadCM3 (GCM and CCAM) – Gatton (40082).

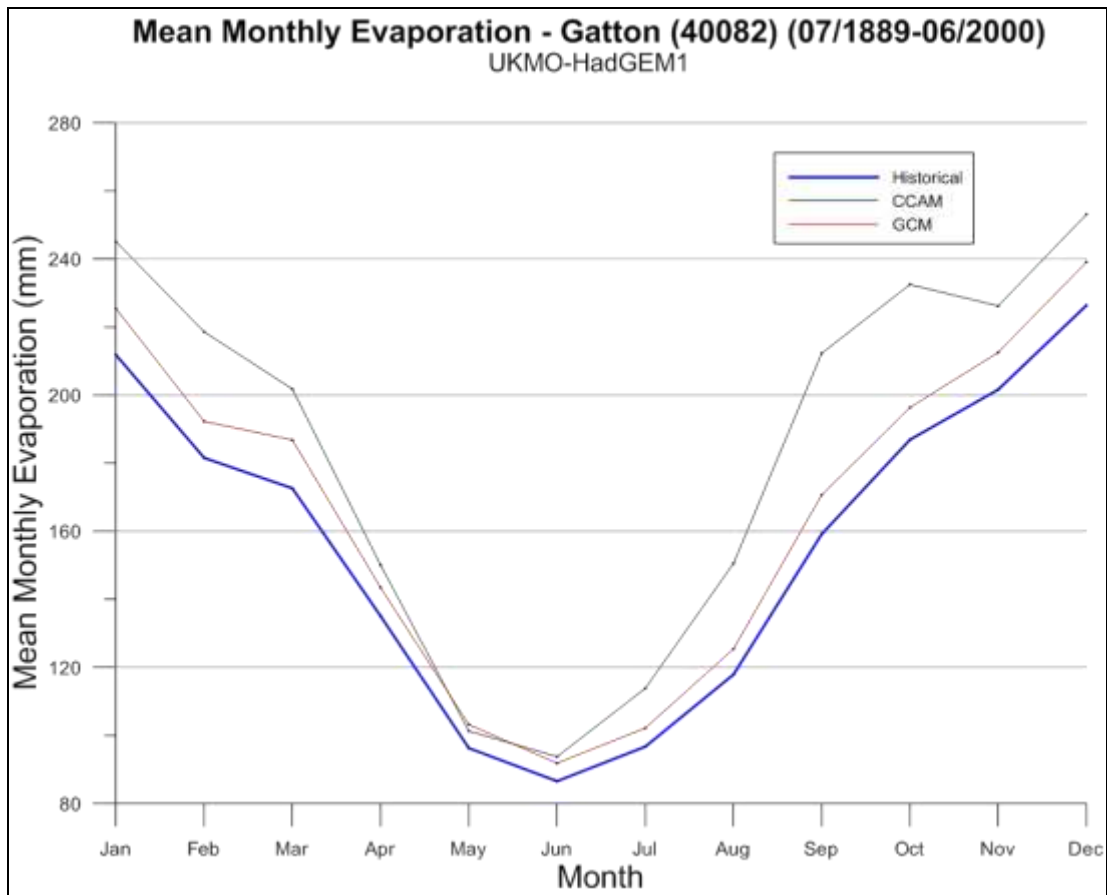


Figure E.10 Mean monthly climate change evaporation – comparison of generation methods for UKMO HadGEM1 (GCM and CCAM) – Gatton (40082).

E.3.2 GCM, CCAM and CCAM PPE1

Table 7.20 Description of Relevant Generation Methods

Generation Method	Gridsize	Description
GCM	Ranging from 100 to 400km	Global circulation models developed by various research institutes around the world
CCAM	~20km	Original dynamically downscaled models using the Conformal-Cubic Atmospheric Model (CCAM) – downscaled to 20km
CCAM PPE1	~ 8km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 8km
CCAM PPE1	~20km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 20km

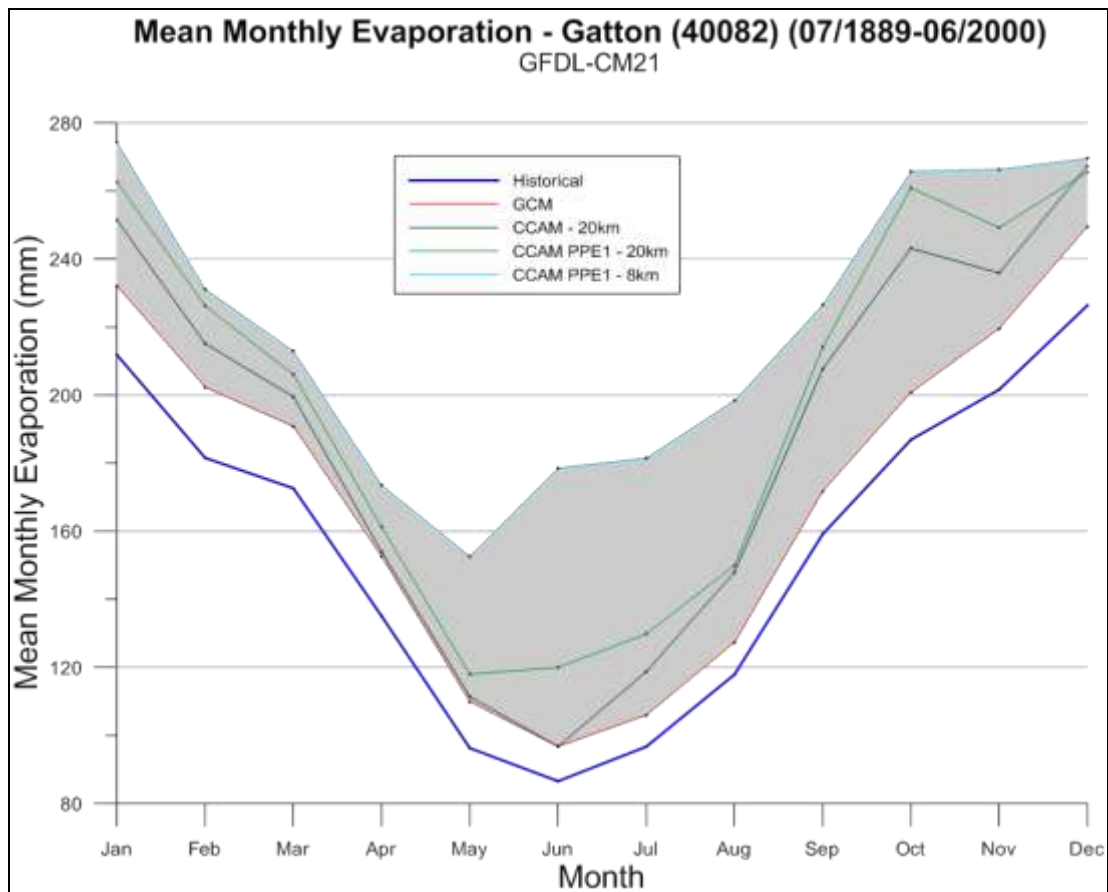


Figure E.11 Mean monthly climate change evaporation – comparison of generation methods for GFDL CM21 (GCM, CCAM and CCAM PPE1) – Gatton (40082).

APPENDIX F Climate Change Model Input Data – Inflow

F.1 Global Circulation Model Method

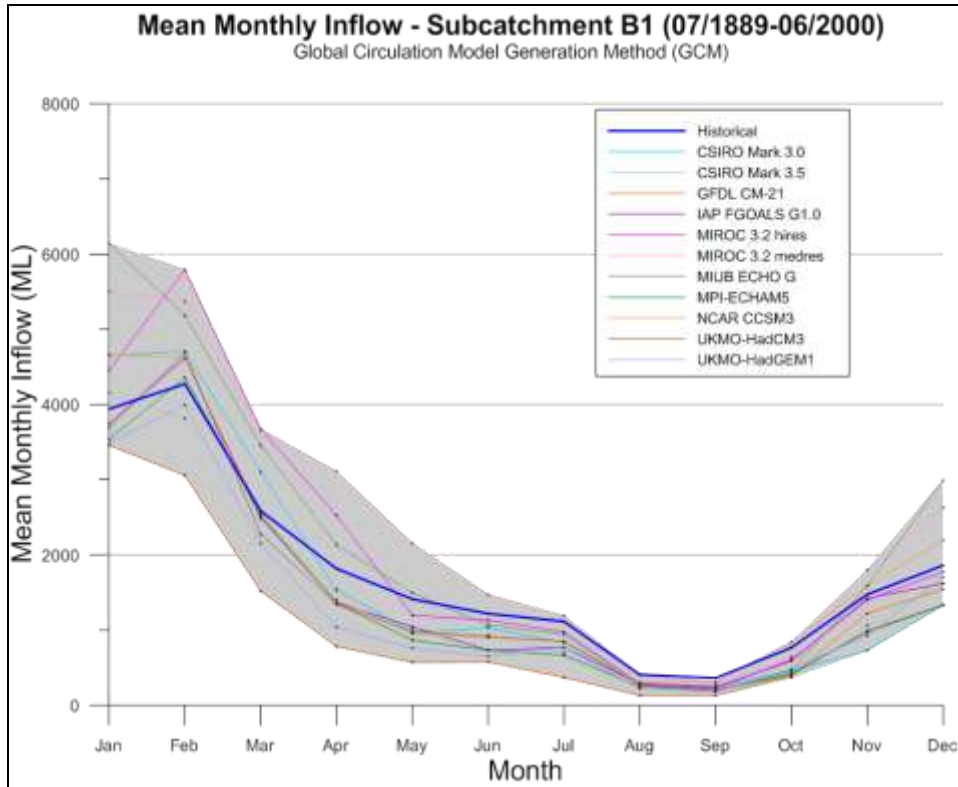


Figure F.1 Mean monthly climate change inflow – GCM – Subarea B1 (Moogerah Dam Site).

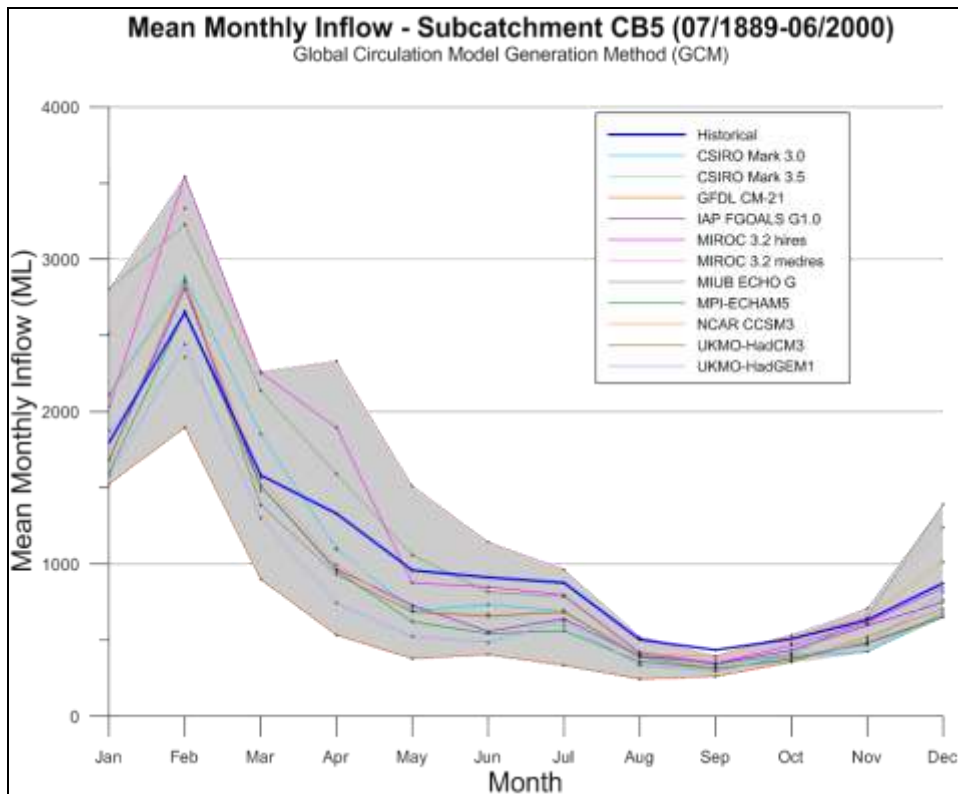


Figure F.2 Mean monthly climate change inflow – GCM – Subarea CB5.

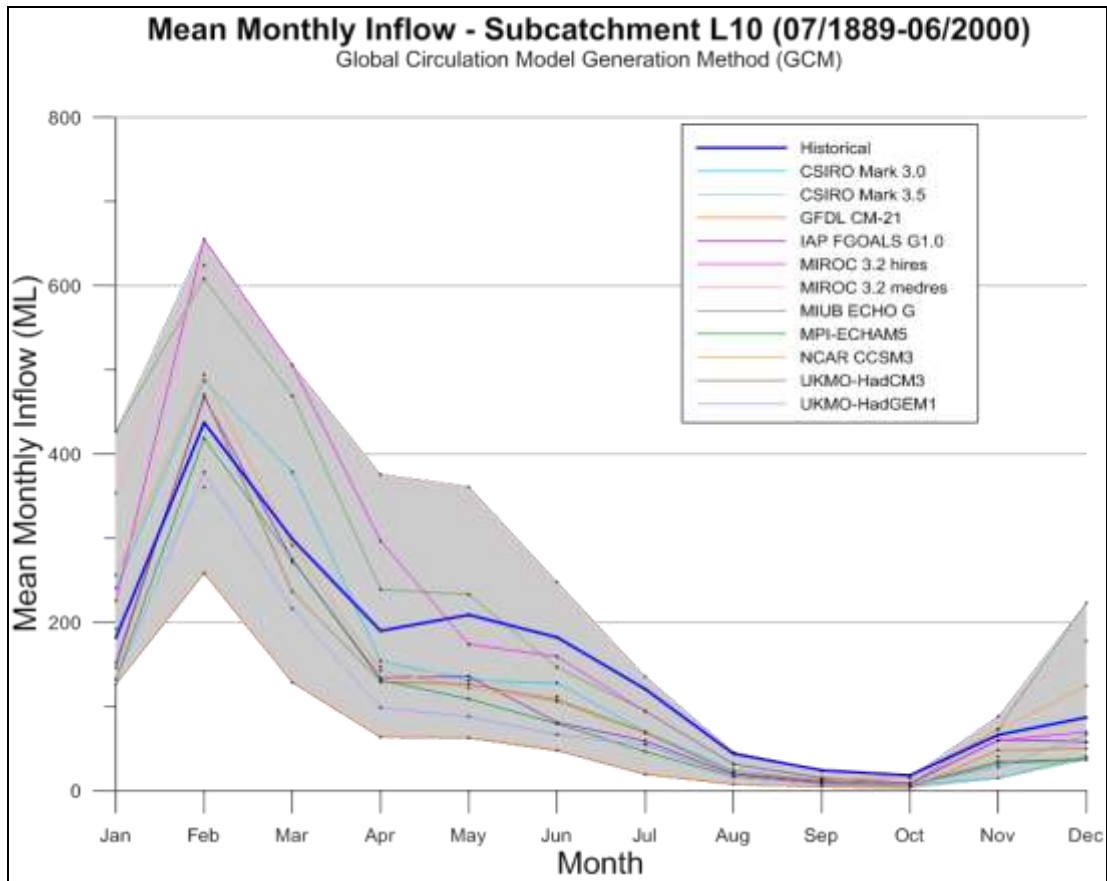


Figure F.3 Mean monthly climate change inflow – GCM – Subarea L10.

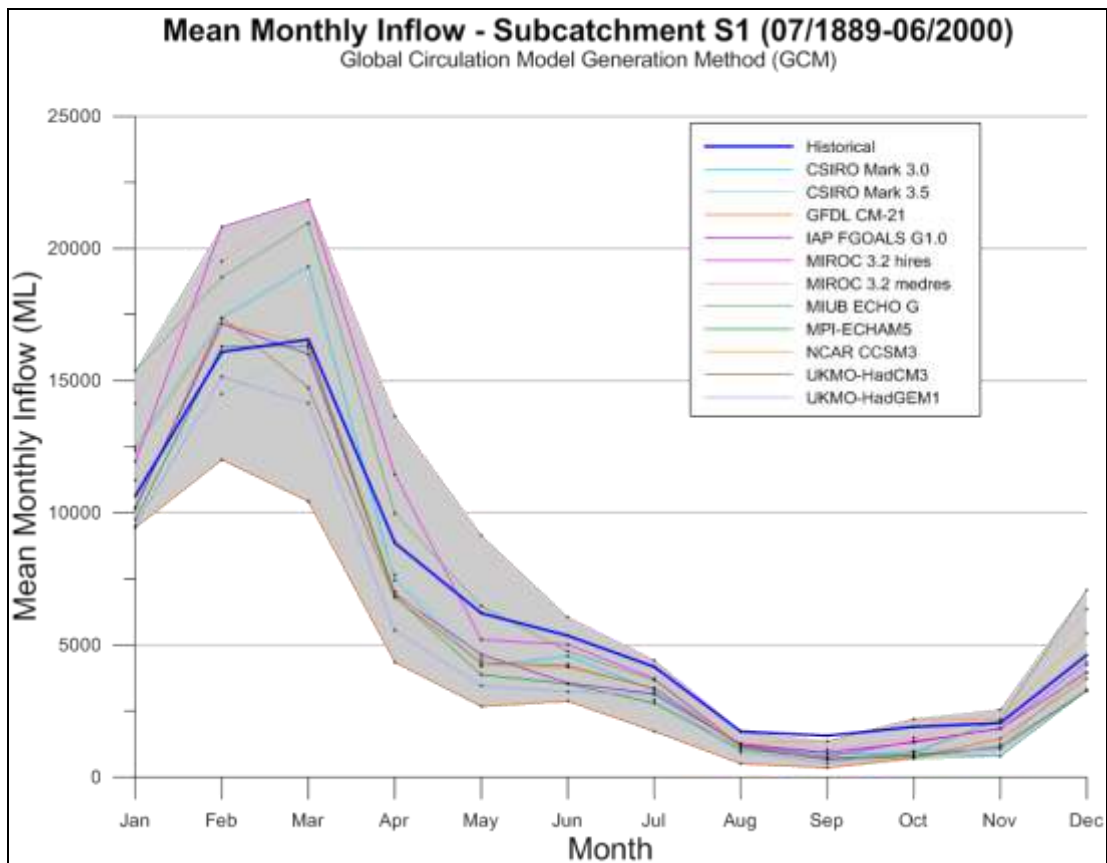


Figure F.4 Mean monthly climate change inflow – GCM – Subarea S1.

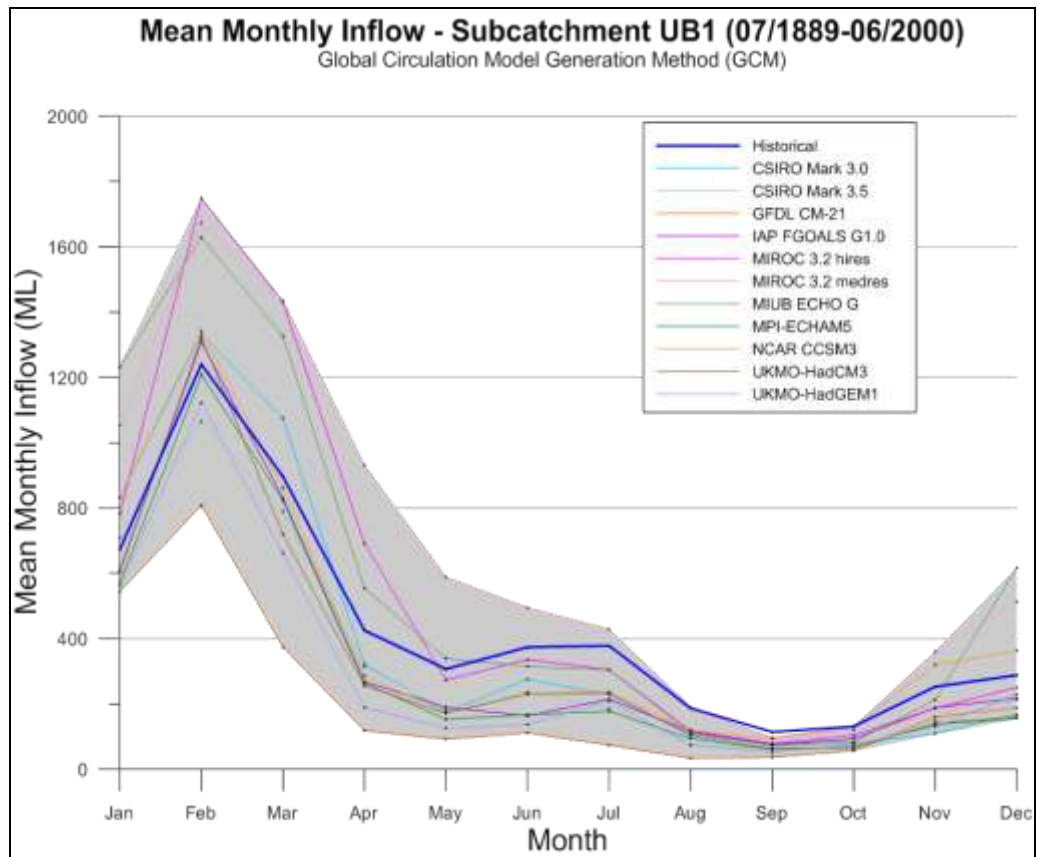


Figure F.5 Mean monthly climate change inflow – GCM – Subarea UB1.

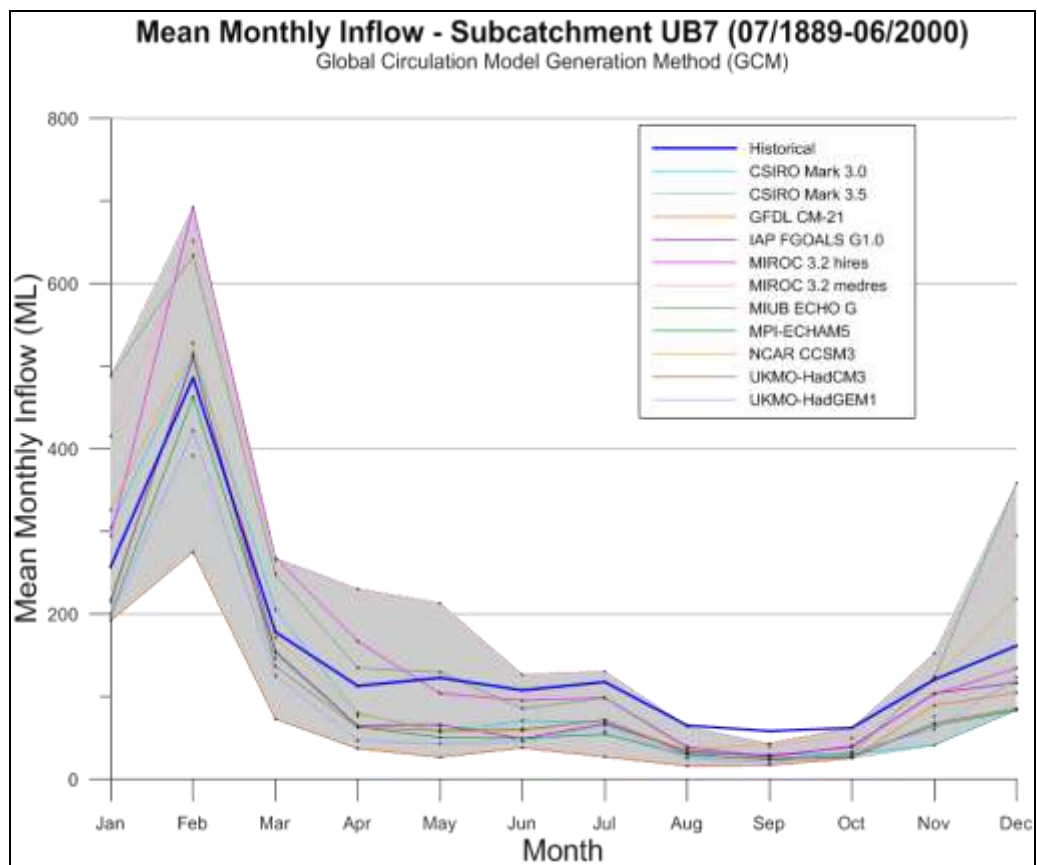


Figure F.6 Mean monthly climate change inflow – GCM – Subarea UB7.

F.2 Downscaled Generation Method

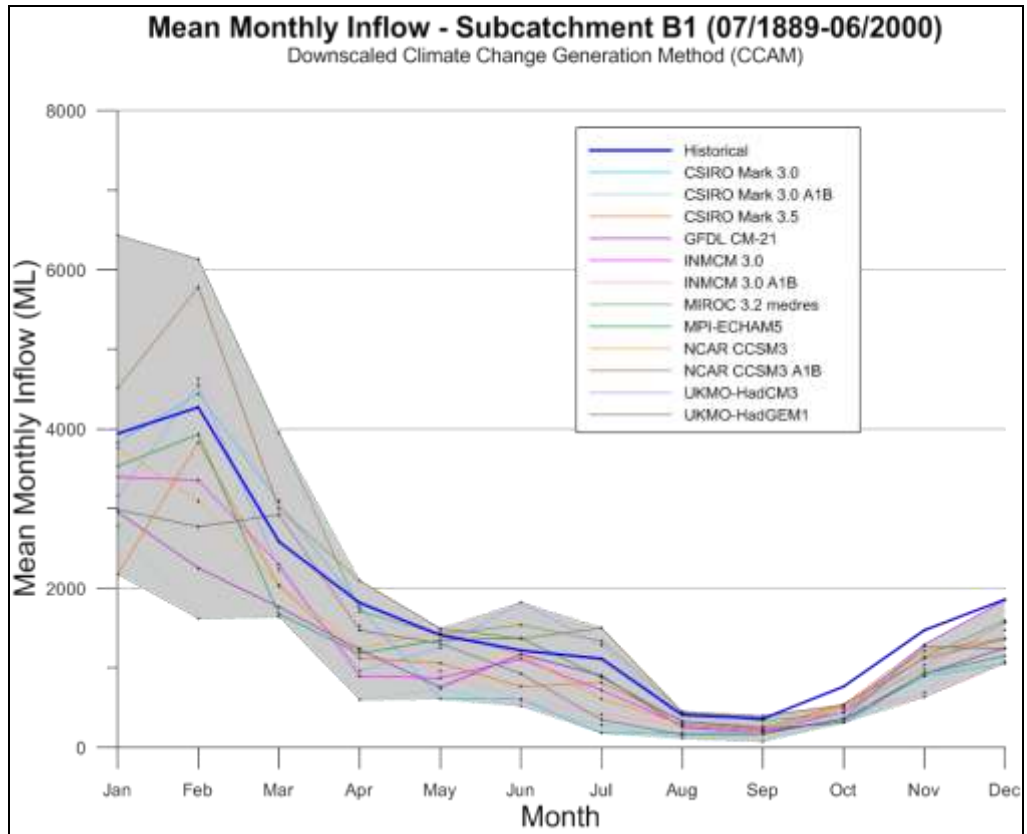


Figure F.7 Mean monthly climate change inflow – CCAM – Subarea B1 (Moogerah Dam Site).

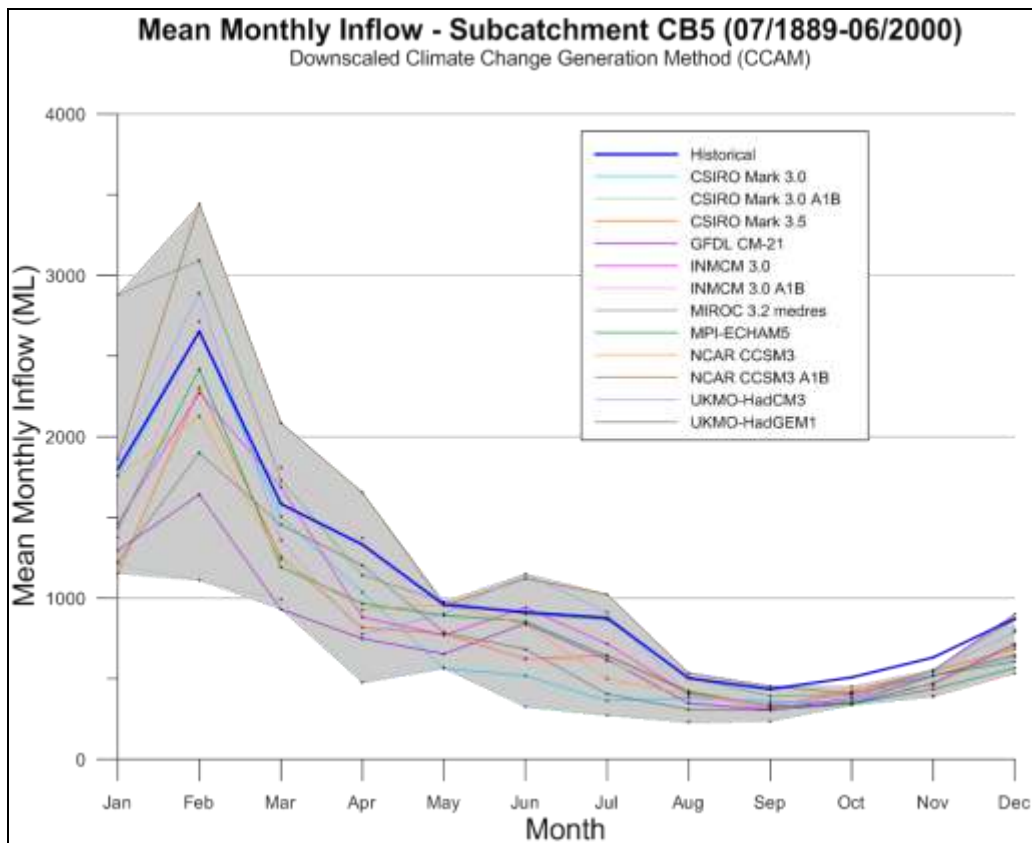


Figure F.8 Mean monthly climate change inflow – CCAM – Subarea CB5.

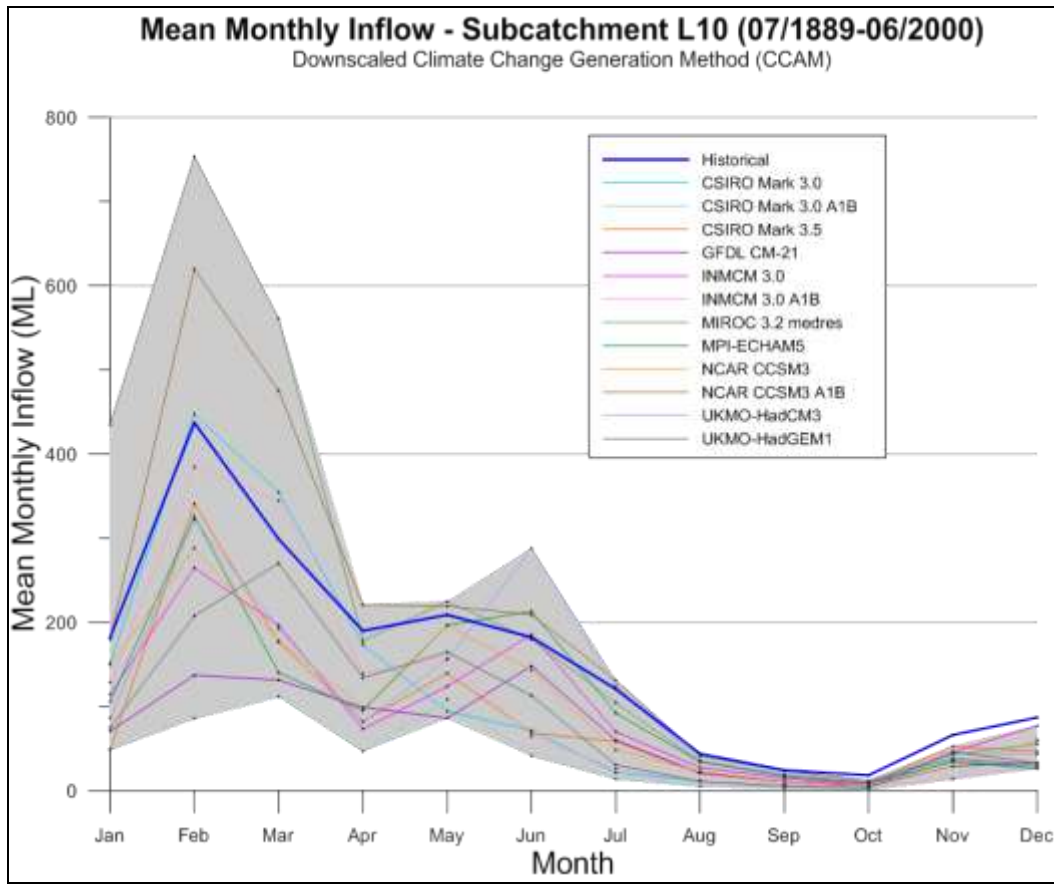


Figure F.9 Mean monthly climate change inflow – CCAM – Subarea L10.

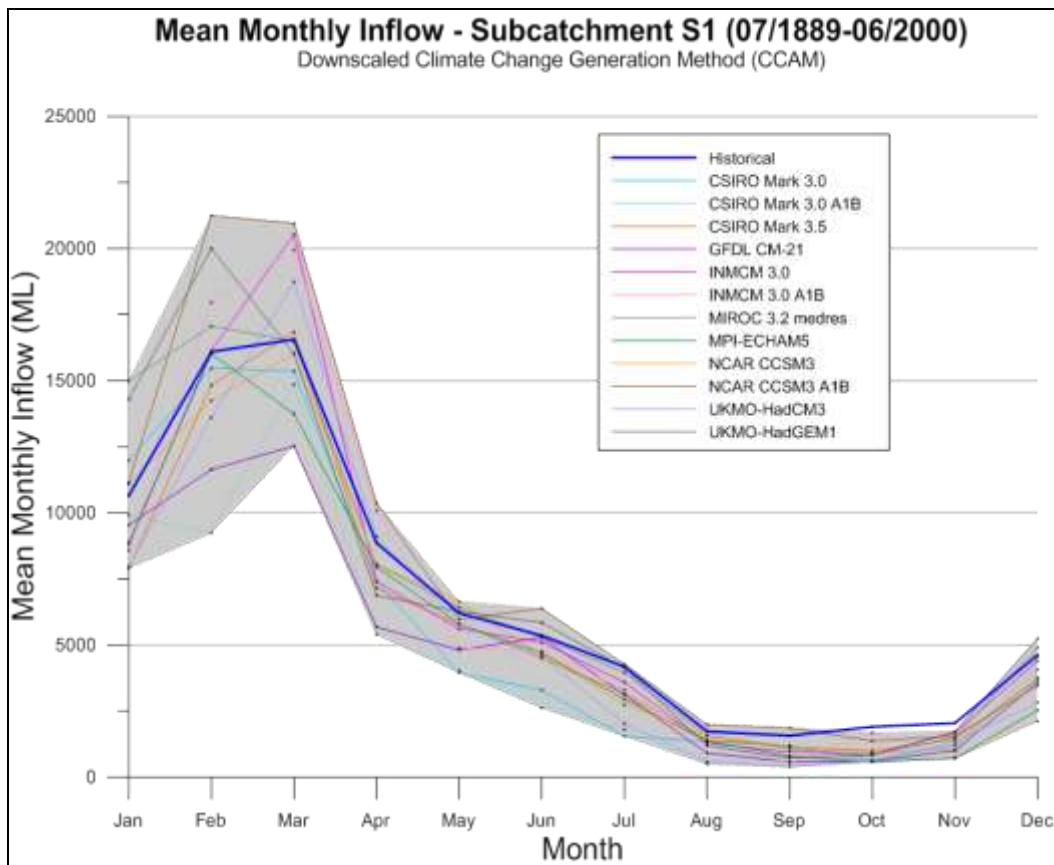


Figure F.10 Mean monthly climate change inflow – CCAM – Subarea S1.

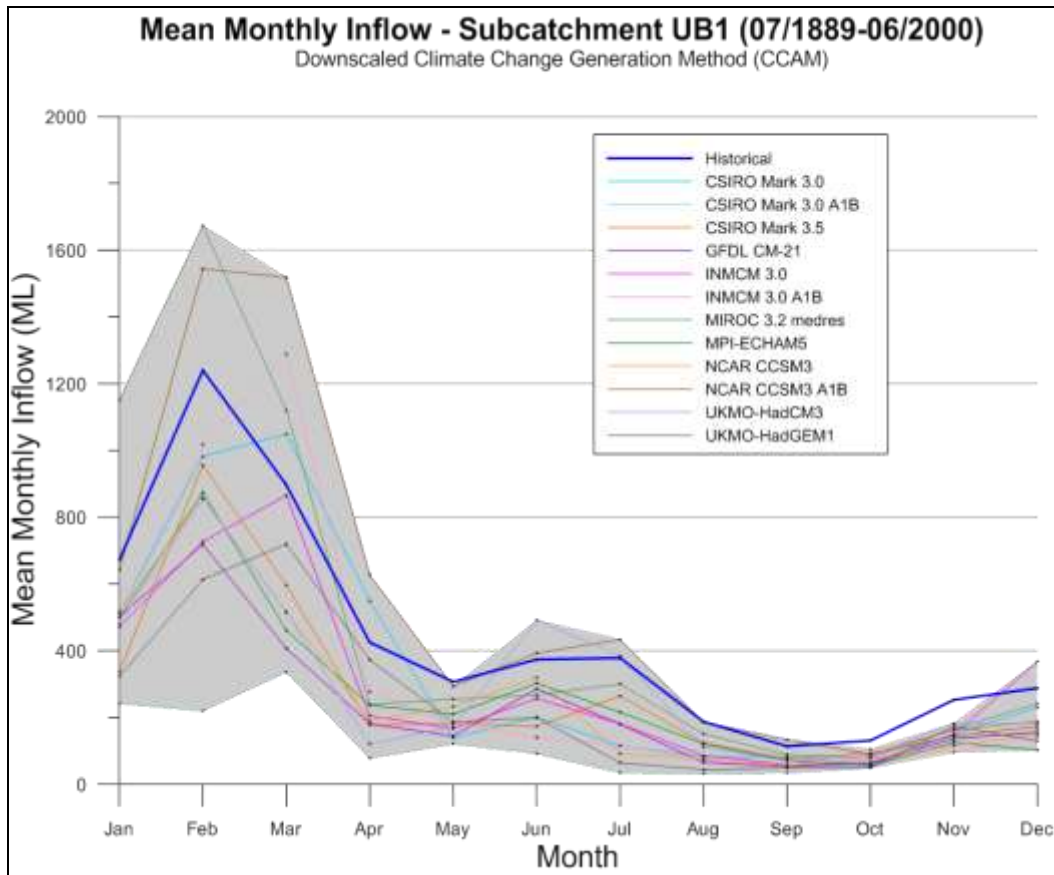


Figure F.11 Mean monthly climate change inflow – CCAM – Subarea UB1.

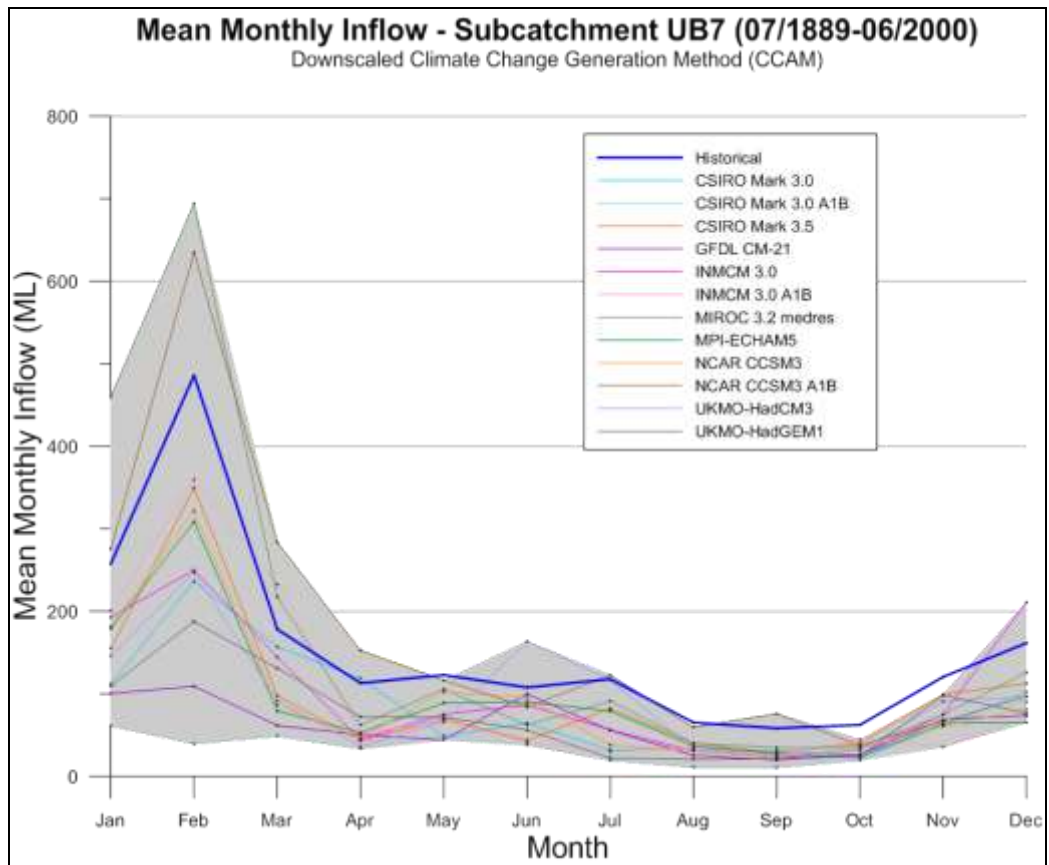


Figure F.12 Mean monthly climate change inflow – CCAM – Subarea UB7.

F.3 Comparison of Generation Methods

F.3.1 GCM and CCAM

Table 7.21 Description of Relevant Generation Methods.

Generation Method	Gridsize	Description
GCM	Ranging from 100 to 400km	Global circulation models developed by various research institutes around the world
CCAM	~20km	Original dynamically downscaled models using the Conformal-Cubic Atmospheric Model (CCAM) – downscaled to 20km

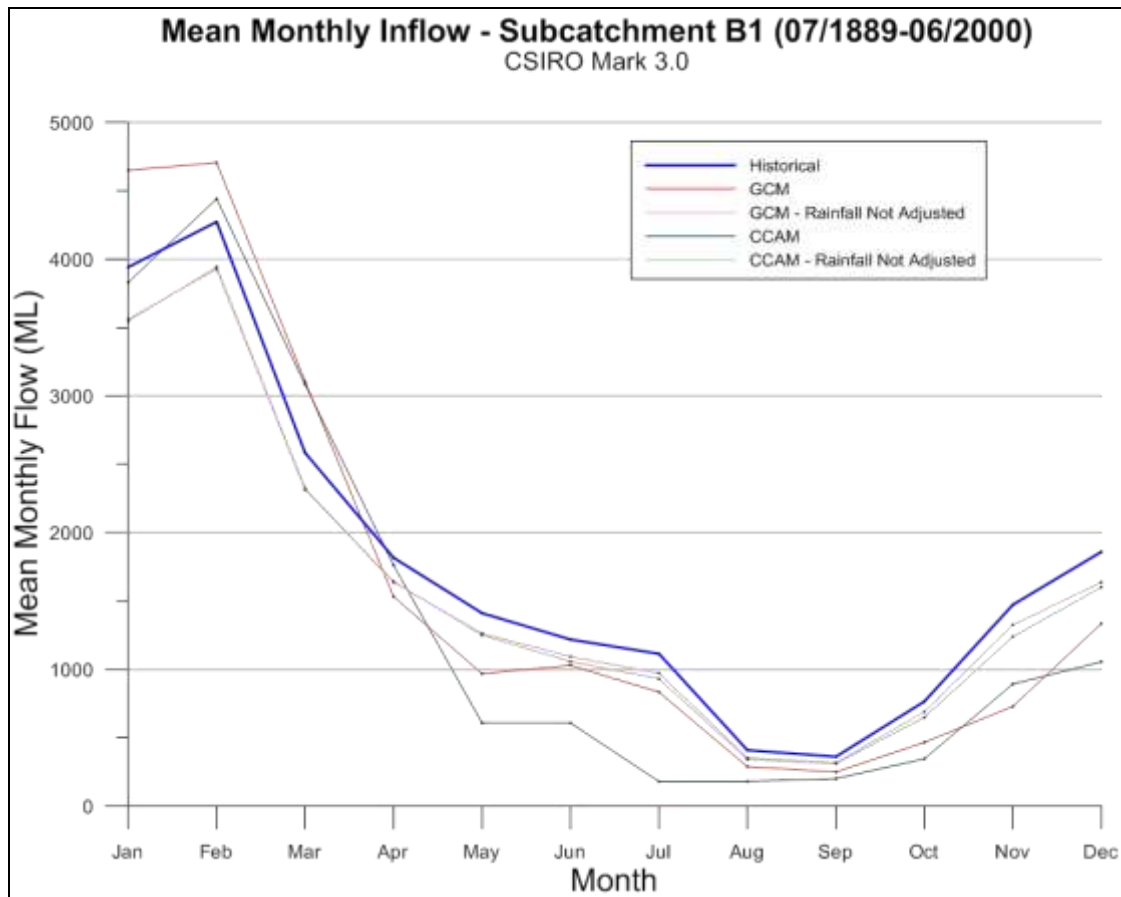


Figure F.13 Mean monthly climate change inflow – comparison of generation methods for CSIRO Mark 3.0 (GCM and CCAM) – Subarea B1 (Moogerah Dam Site).

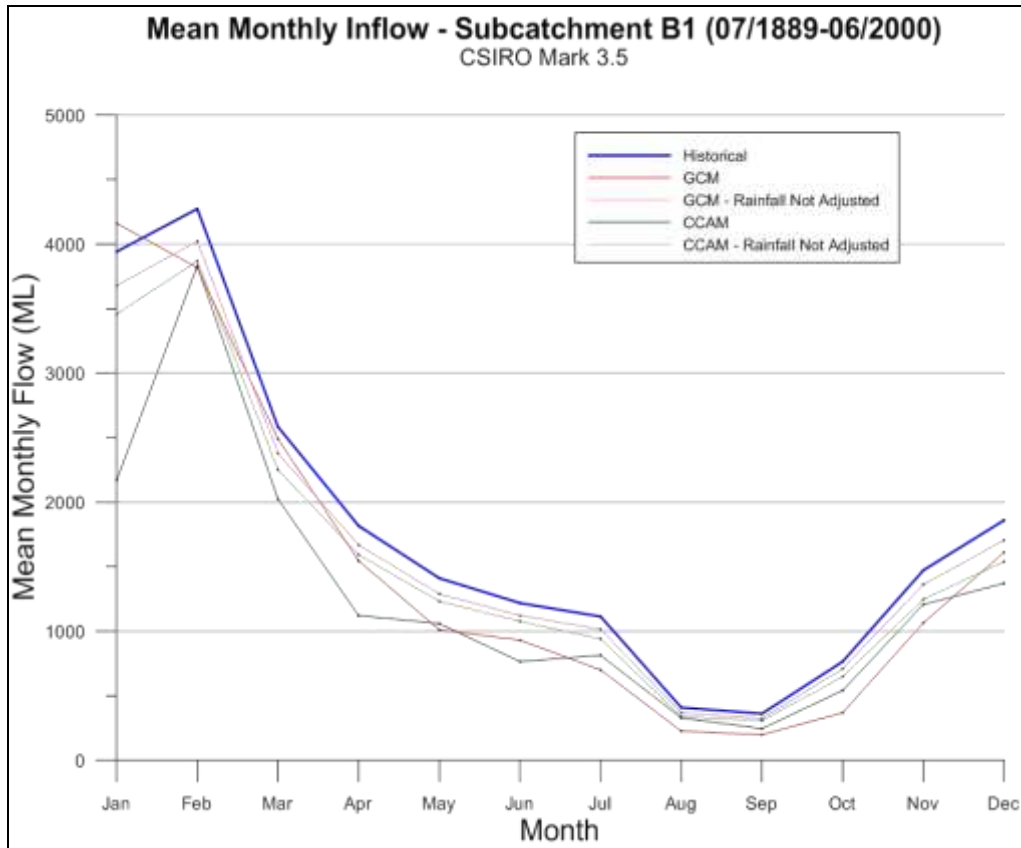


Figure F.14 Mean monthly climate change inflow – comparison of generation methods for CSIRO Mark 3.5 (GCM and CCAM) – Subarea B1 (Moogerah Dam Site).

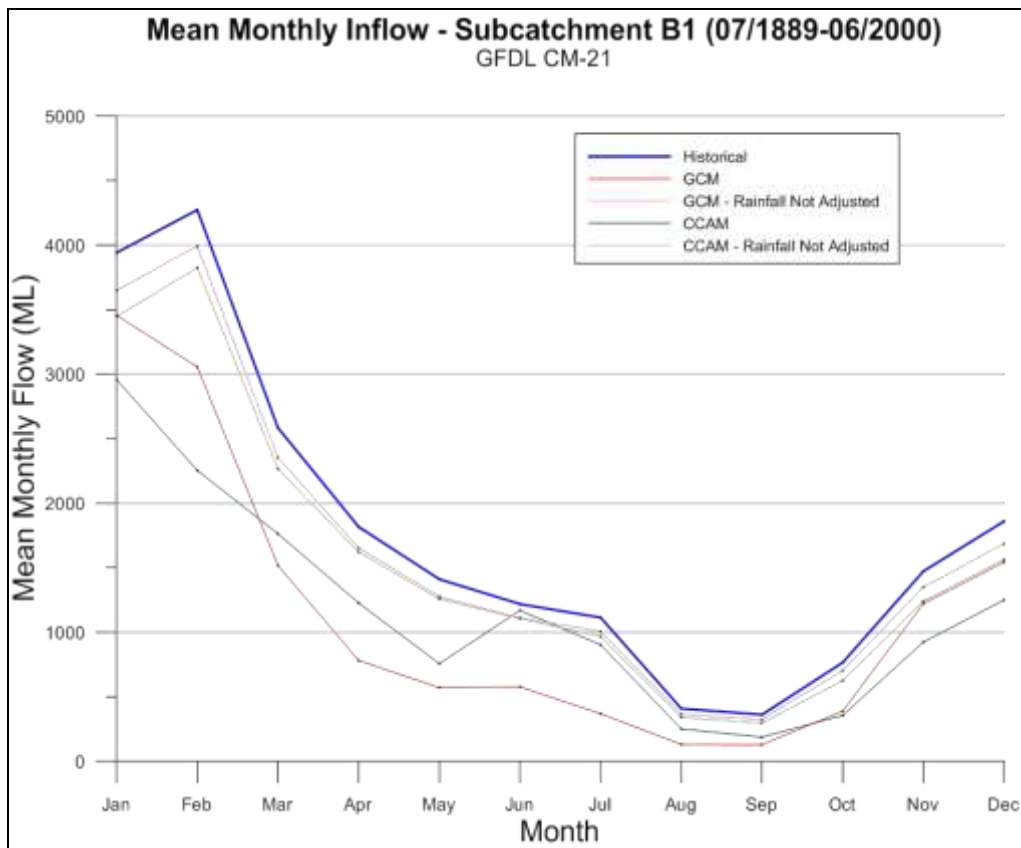


Figure F.15 Mean monthly climate change inflow – comparison of generation methods for GFDL CM21 (GCM and CCAM) – Subarea B1 (Moogerah Dam Site).

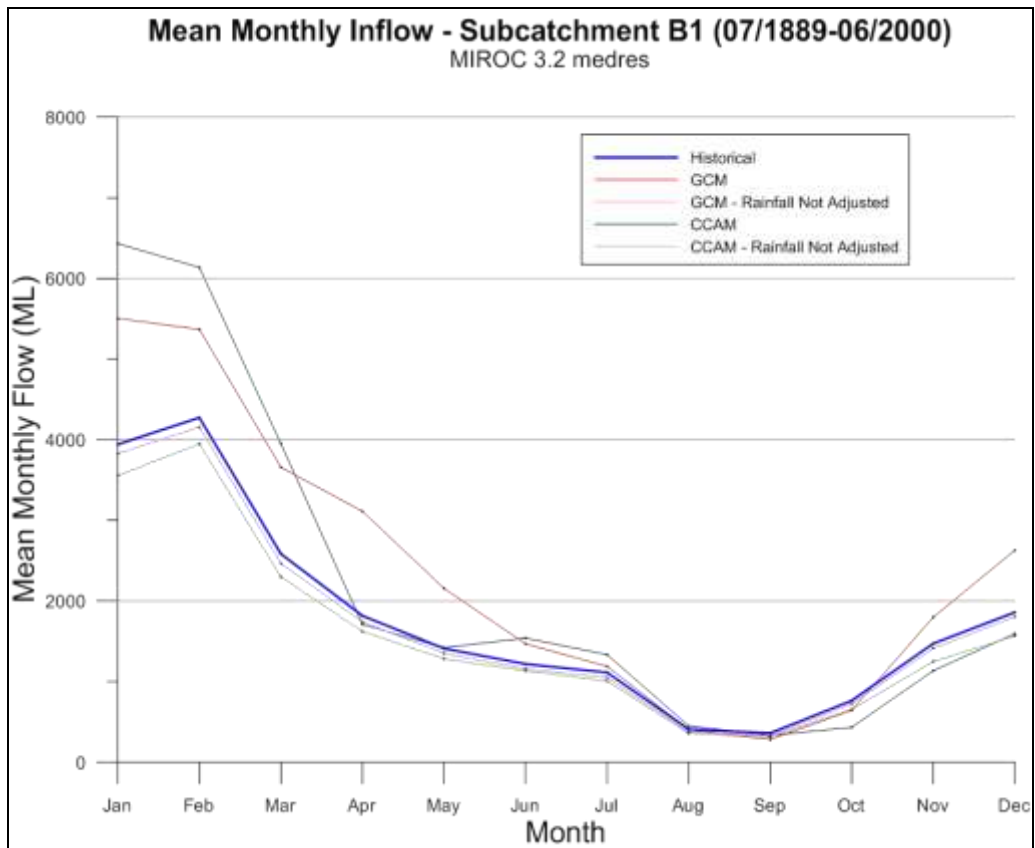


Figure F.16 Mean monthly climate change inflow – comparison of generation methods for MIROC 3.2 medres (GCM and CCAM) – Subarea B1 (Moogerah Dam Site).

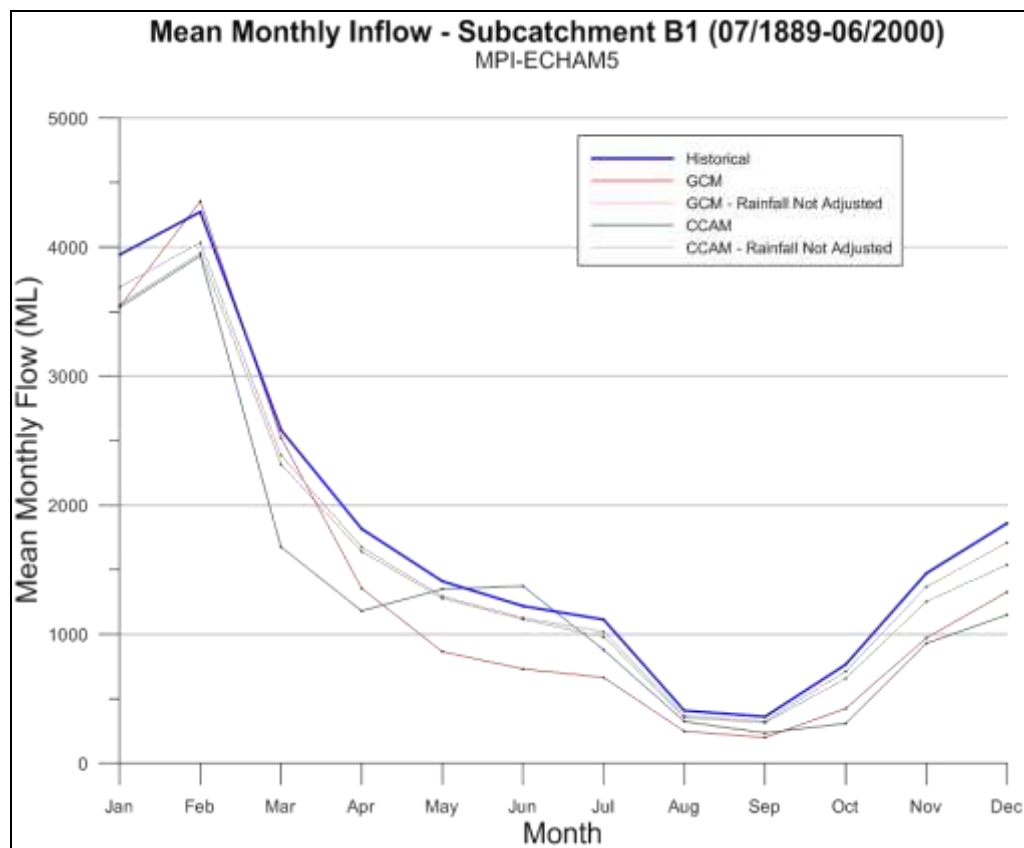


Figure F.17 Mean monthly climate change inflow – comparison of generation methods for MPI ECHAM5 (GCM and CCAM) – Subarea B1 (Moogerah Dam Site).

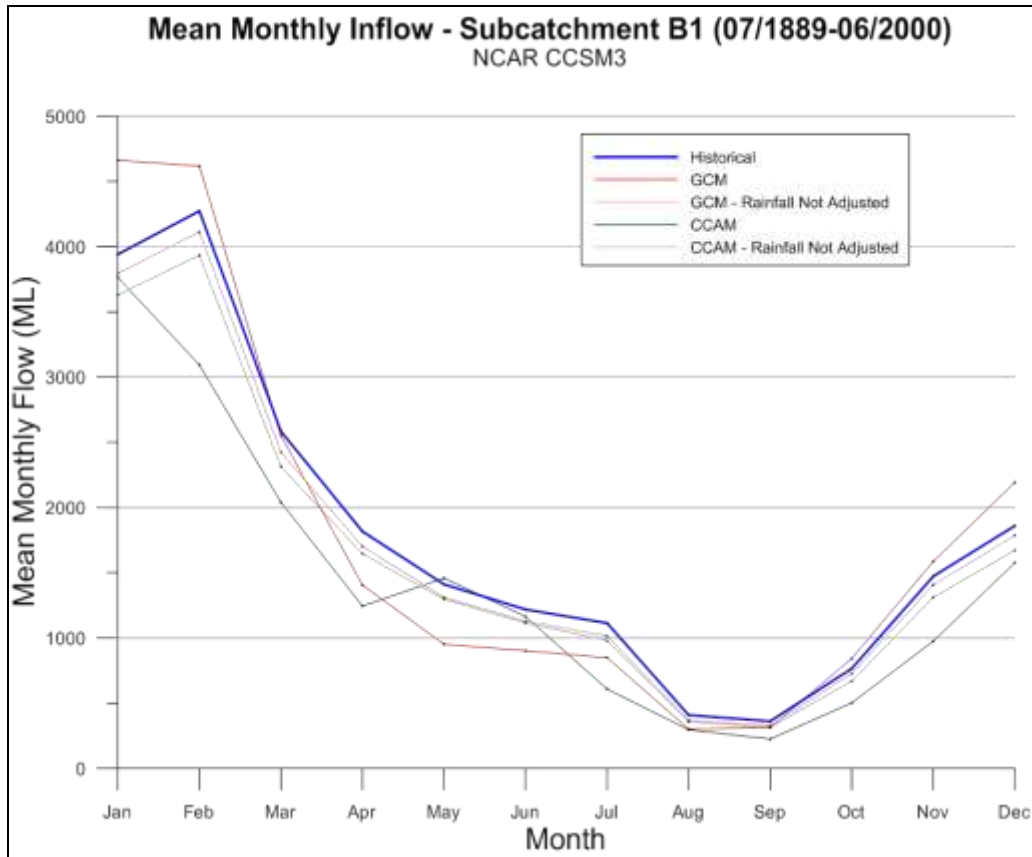


Figure F.18 Mean monthly climate change inflow – comparison of generation methods for NCAR CCSM3 (GCM and CCAM) – Subarea B1 (Moogerah Dam Site).

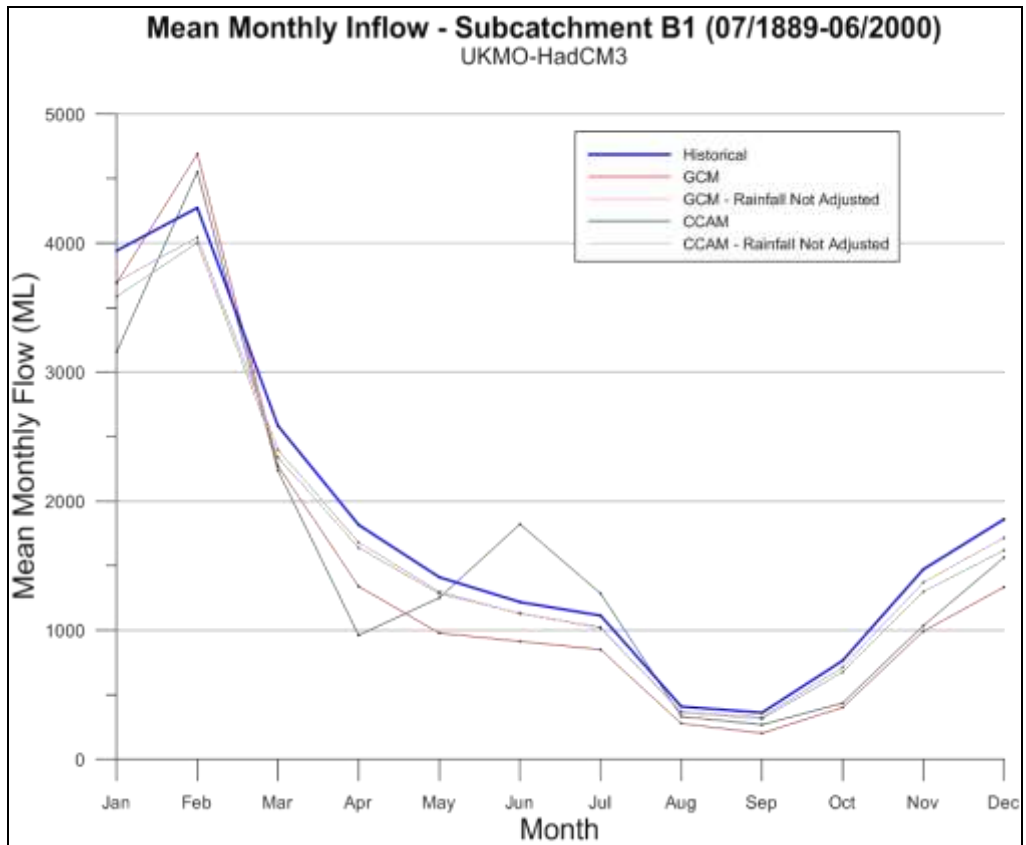


Figure F.19 Mean monthly climate change inflow – comparison of generation methods for UKMO HadCM3 (GCM and CCAM) – Subarea B1 (Moogerah Dam Site).

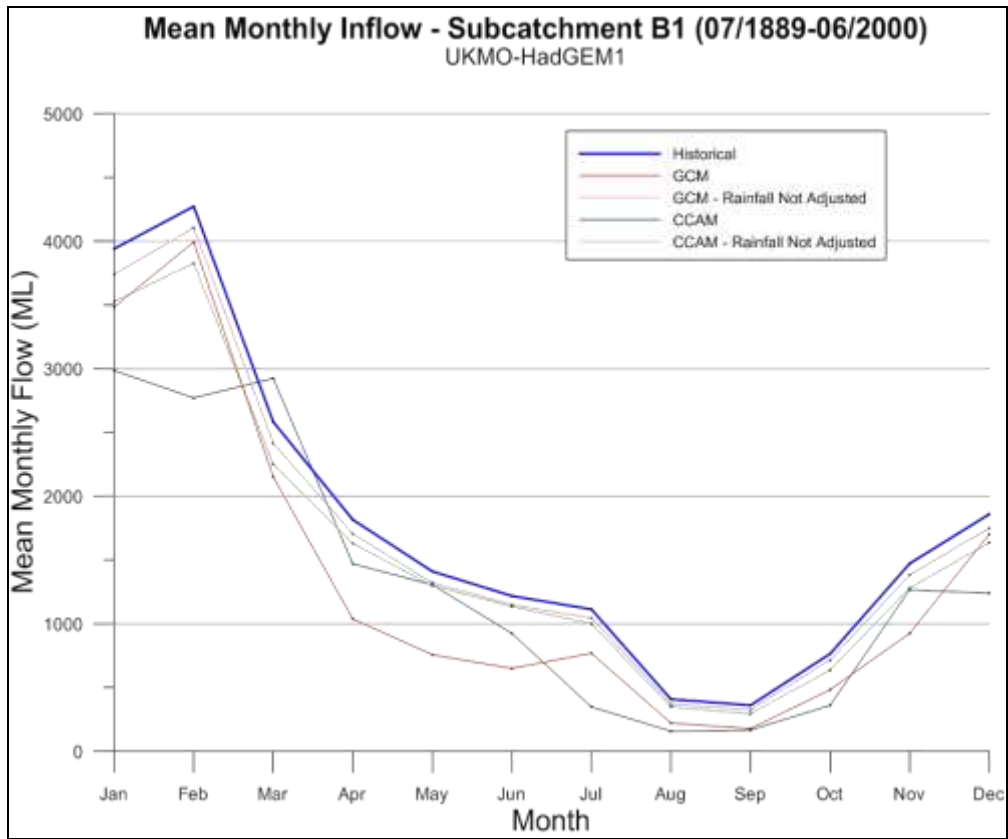


Figure F.20 Mean monthly climate change inflow – comparison of generation methods for UKMO HadGEM1 (GCM and CCAM) – Subarea B1 (Moogerah Dam Site).

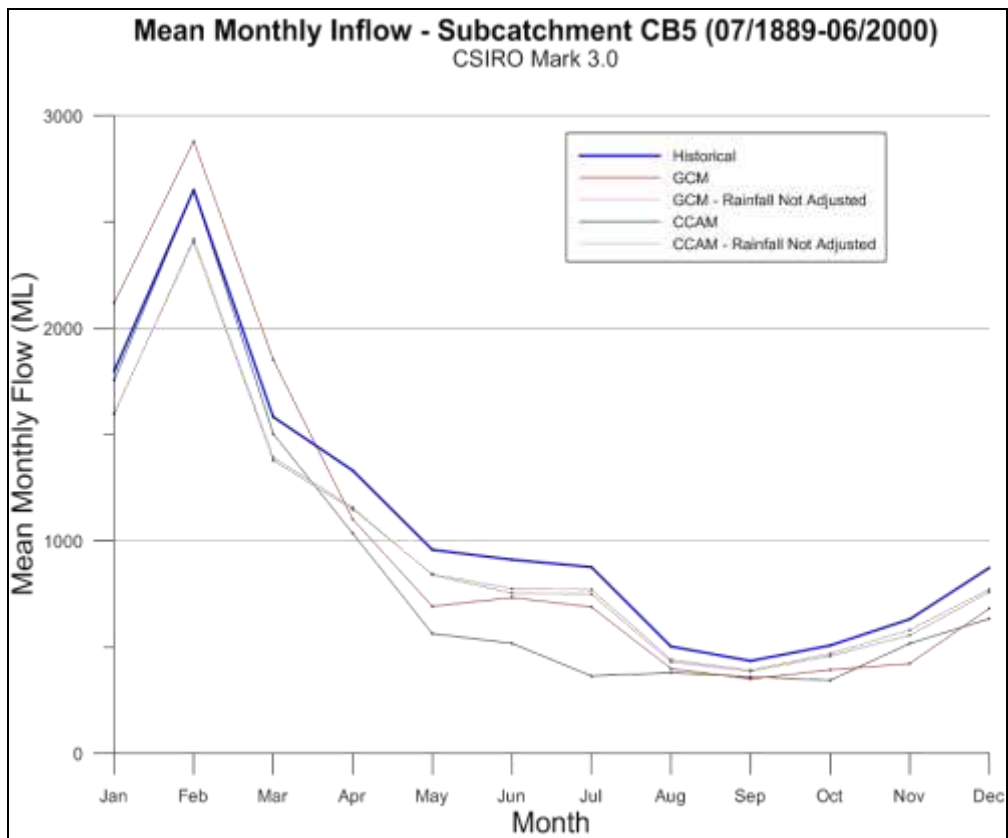


Figure F.21 Mean monthly climate change inflow – comparison of generation methods for CSIRO Mark 3.0 (GCM and CCAM) – Subarea CB5.

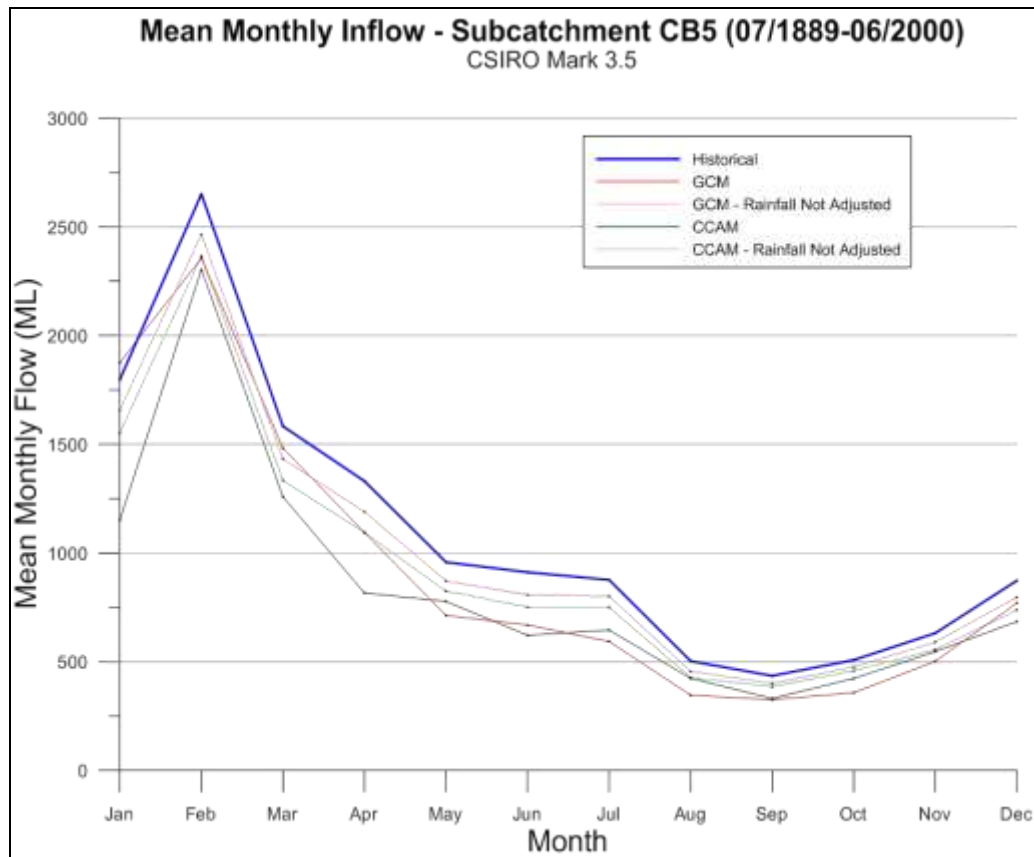


Figure F.22 Mean monthly climate change inflow – comparison of generation methods for CSIRO Mark 3.5 (GCM and CCAM) – Subarea CB5.

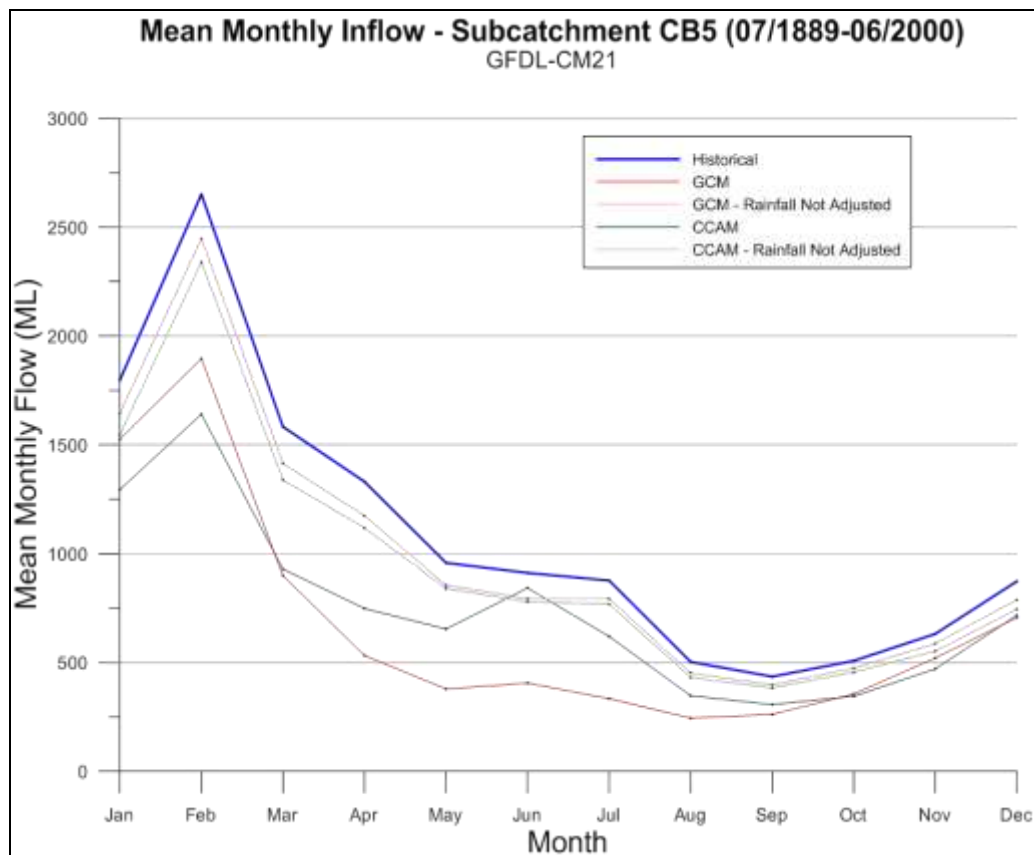


Figure F.23 Mean monthly climate change inflow – comparison of generation methods for GFDL CM21 (GCM and CCAM) – Subarea CB5.

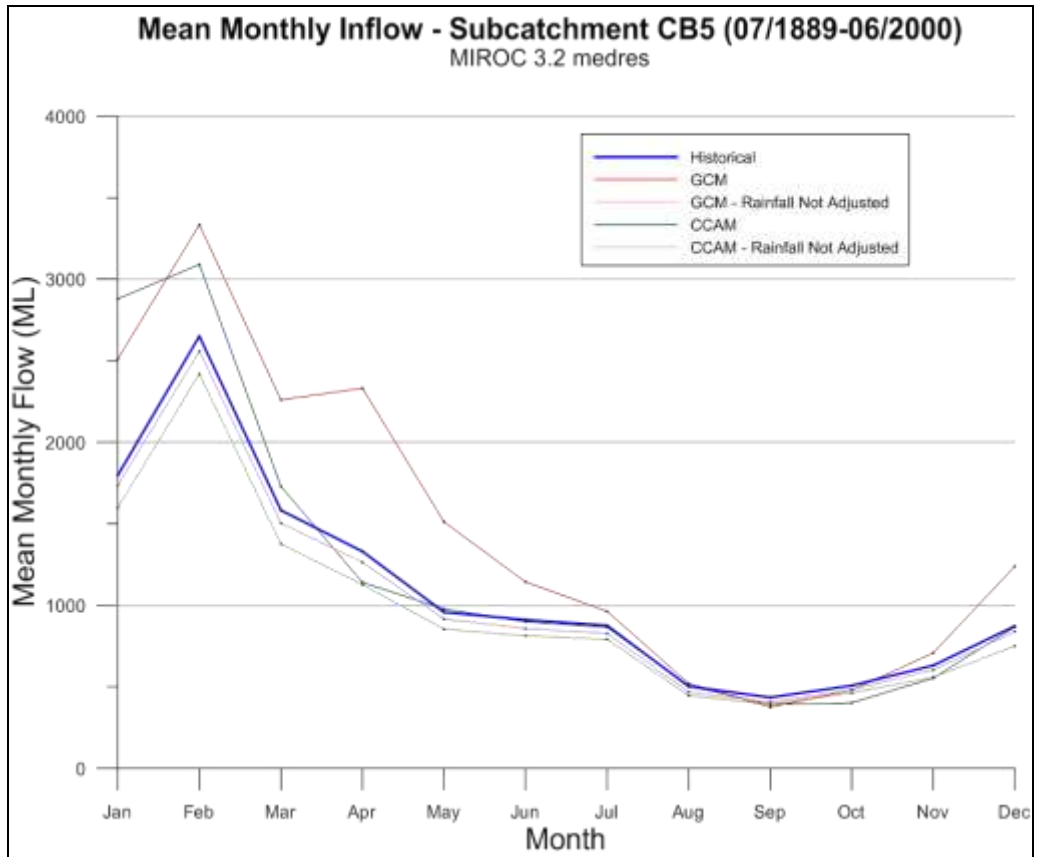


Figure F.24 Mean monthly climate change inflow – comparison of generation methods for MIROC 3.2 medres (GCM and CCAM) – Subarea CB5.

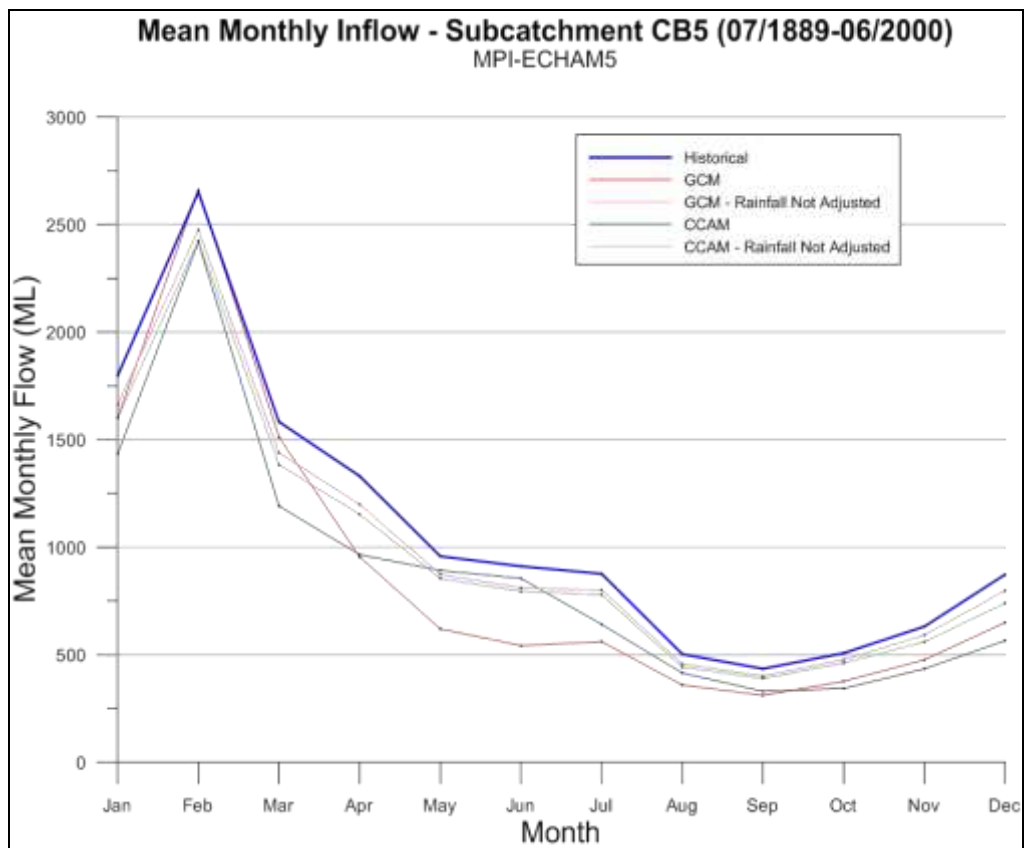


Figure F.25 Mean monthly climate change inflow – comparison of generation methods for MPI ECHAM5 (GCM and CCAM) – Subarea CB5.

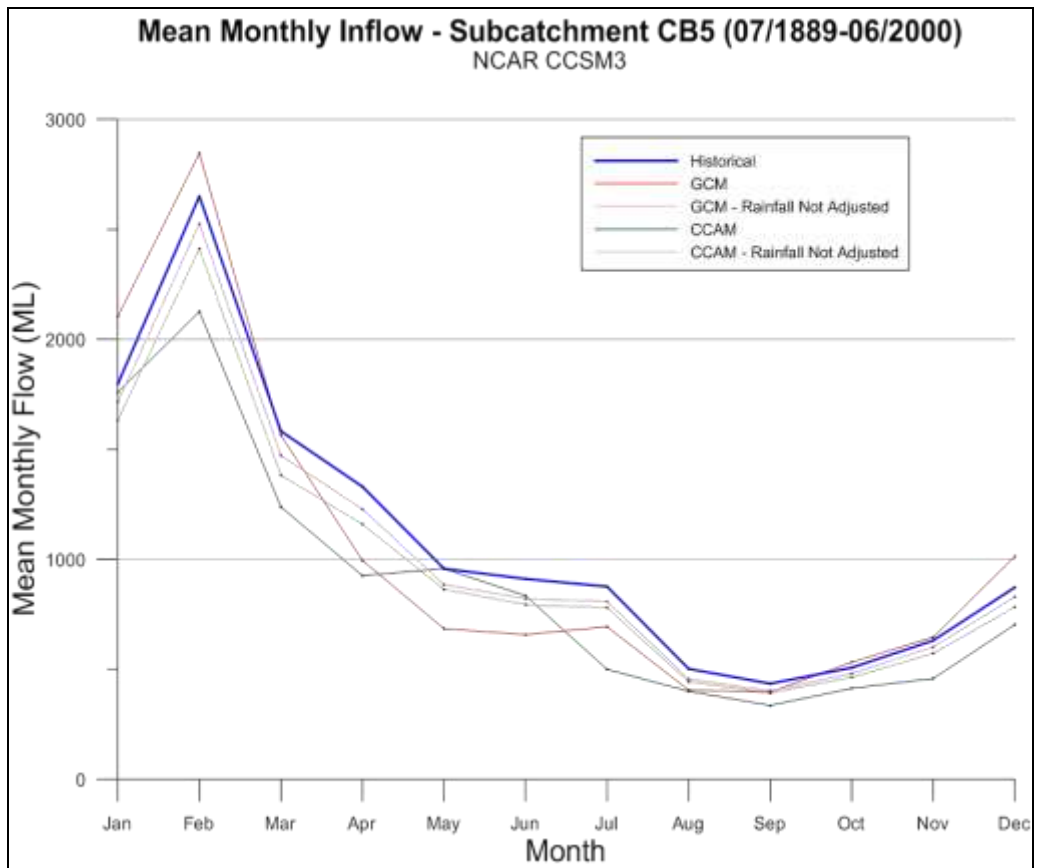


Figure F.26 Mean monthly climate change inflow – comparison of generation methods for NCAR CCSM3 (GCM and CCAM) – Subarea CB5.

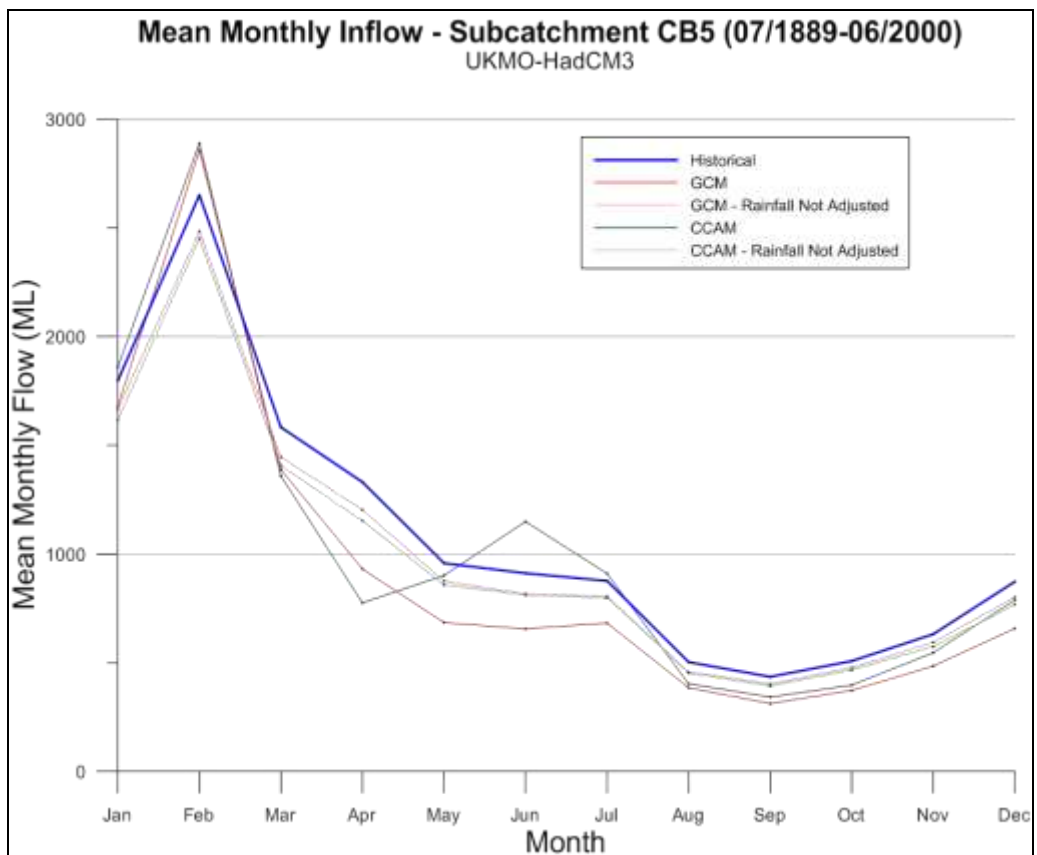


Figure F.27 Mean monthly climate change inflow – comparison of generation methods for UKMO HadCM3 (GCM and CCAM) – Subarea CB5.

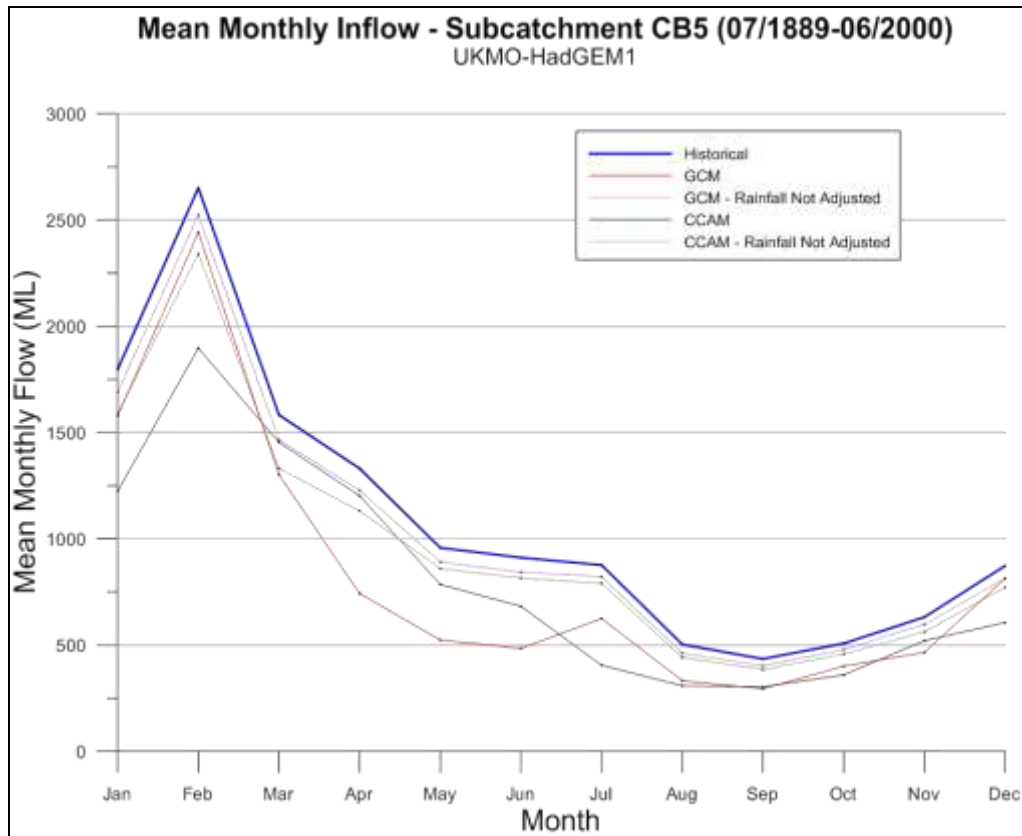


Figure F.28 Mean monthly climate change inflow – comparison of generation methods for UKMO HadGEM1 (GCM and CCAM) – Subarea CB5.

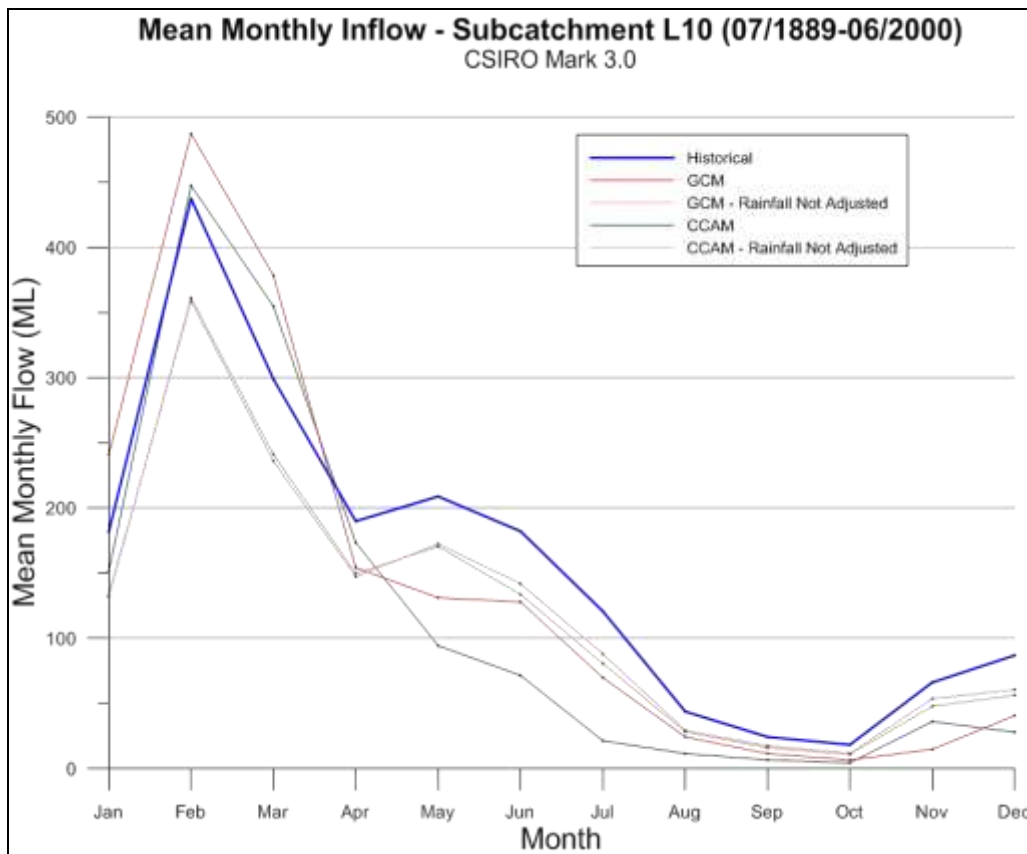


Figure F.29 Mean monthly climate change inflow – comparison of generation methods for CSIRO Mark 3.0 (GCM and CCAM) – Subarea L10.

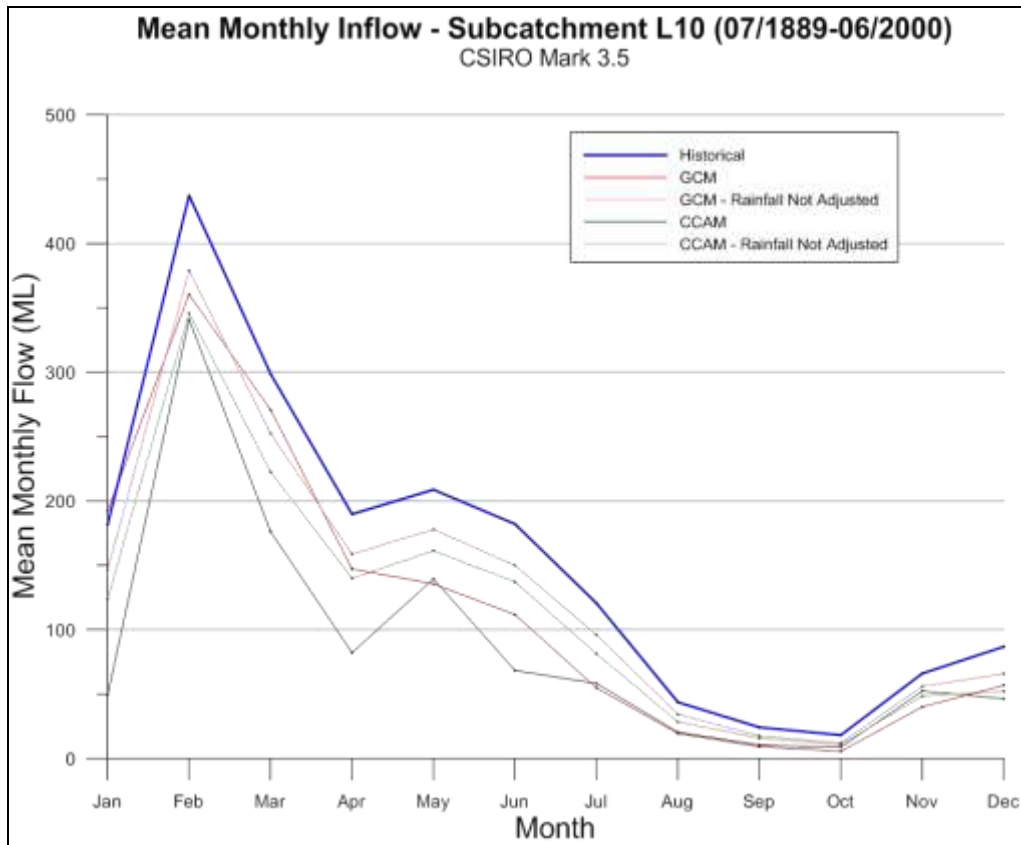


Figure F.30 Mean monthly climate change inflow – comparison of generation methods for CSIRO Mark 3.5 (GCM and CCAM) – Subarea L10.

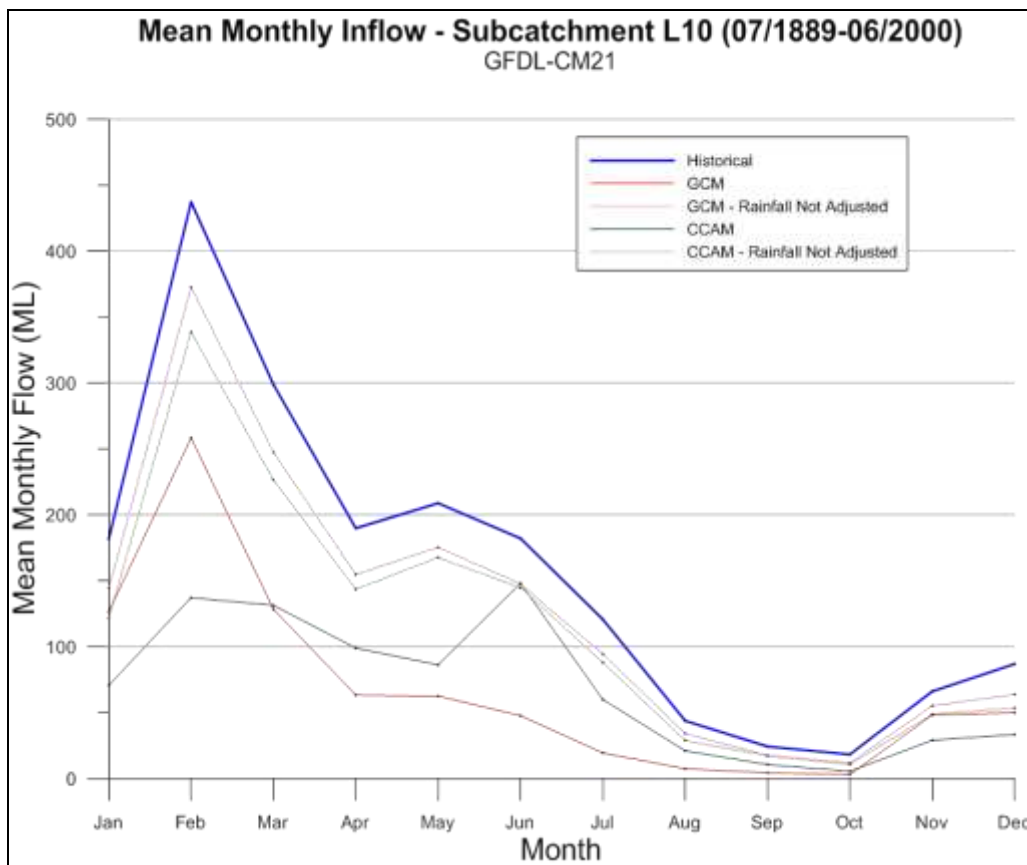


Figure F.31 Mean monthly climate change inflow – comparison of generation methods for GFDL CM21 (GCM and CCAM) – Subarea L10.

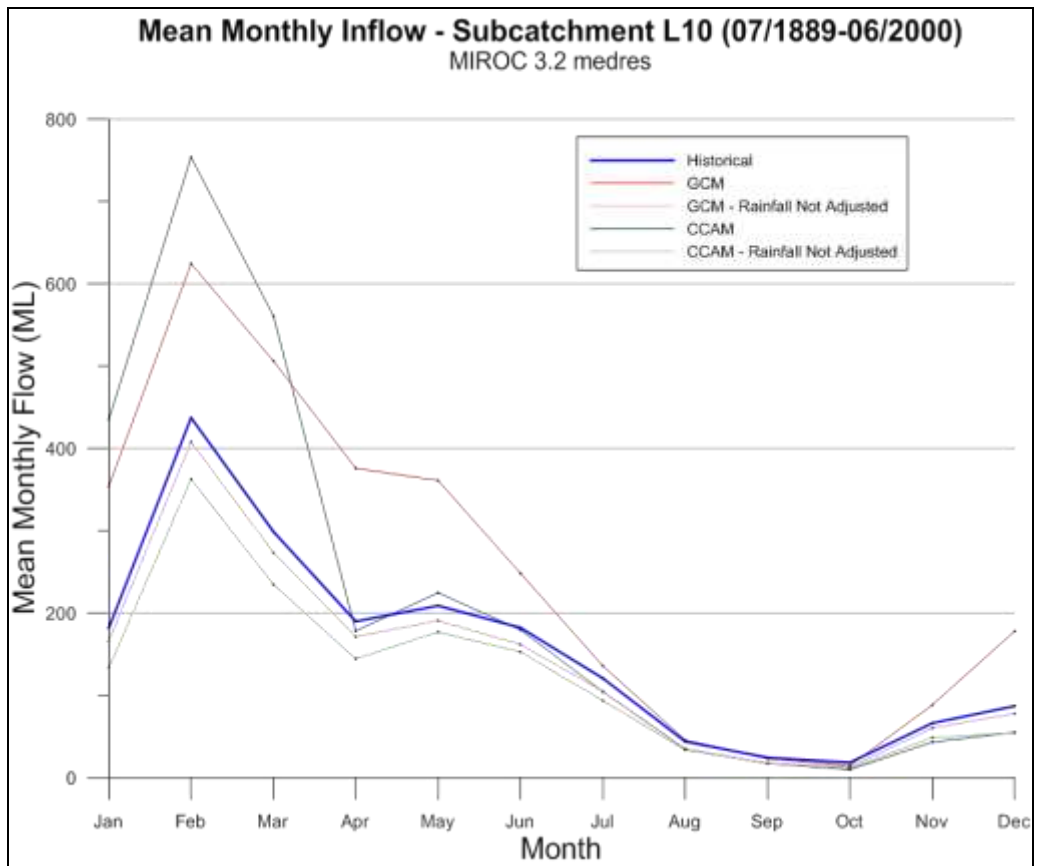


Figure F.32 Mean monthly climate change inflow – comparison of generation methods for MIROC 3.2 medres (GCM and CCAM) – Subarea L10.

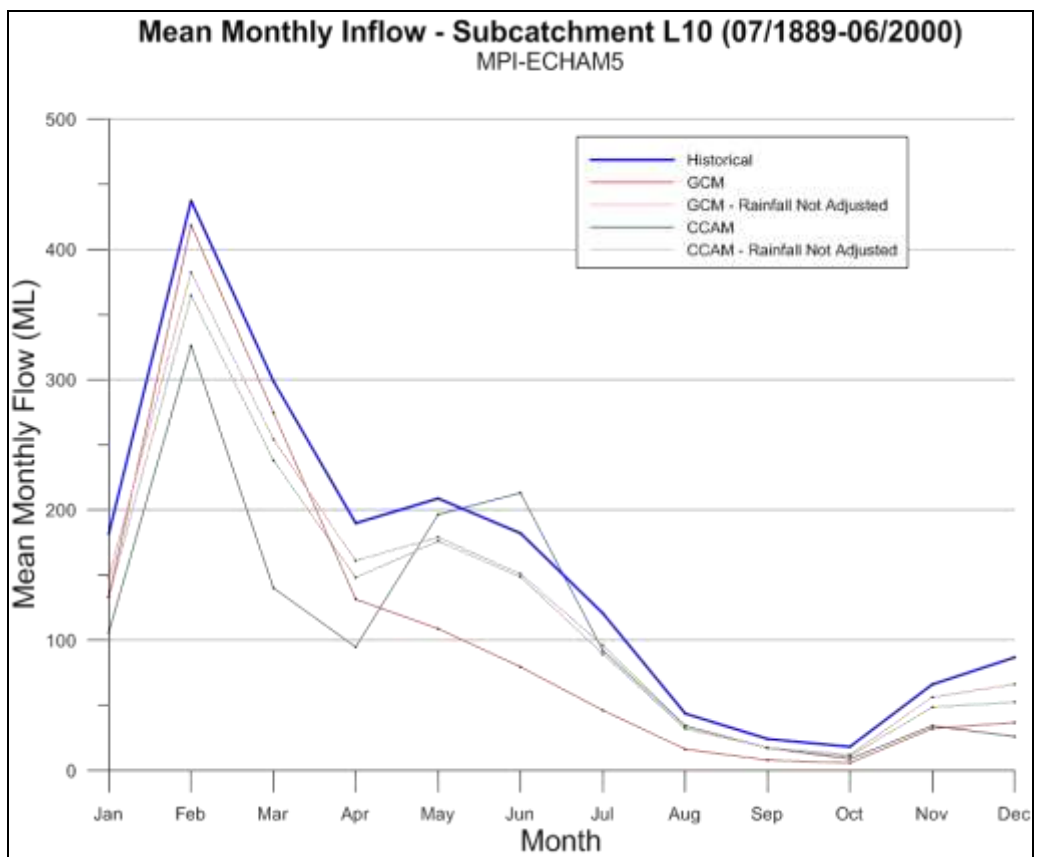


Figure F.33 Mean monthly climate change inflow – comparison of generation methods for MPI ECHAM5 (GCM and CCAM) – Subarea L10.

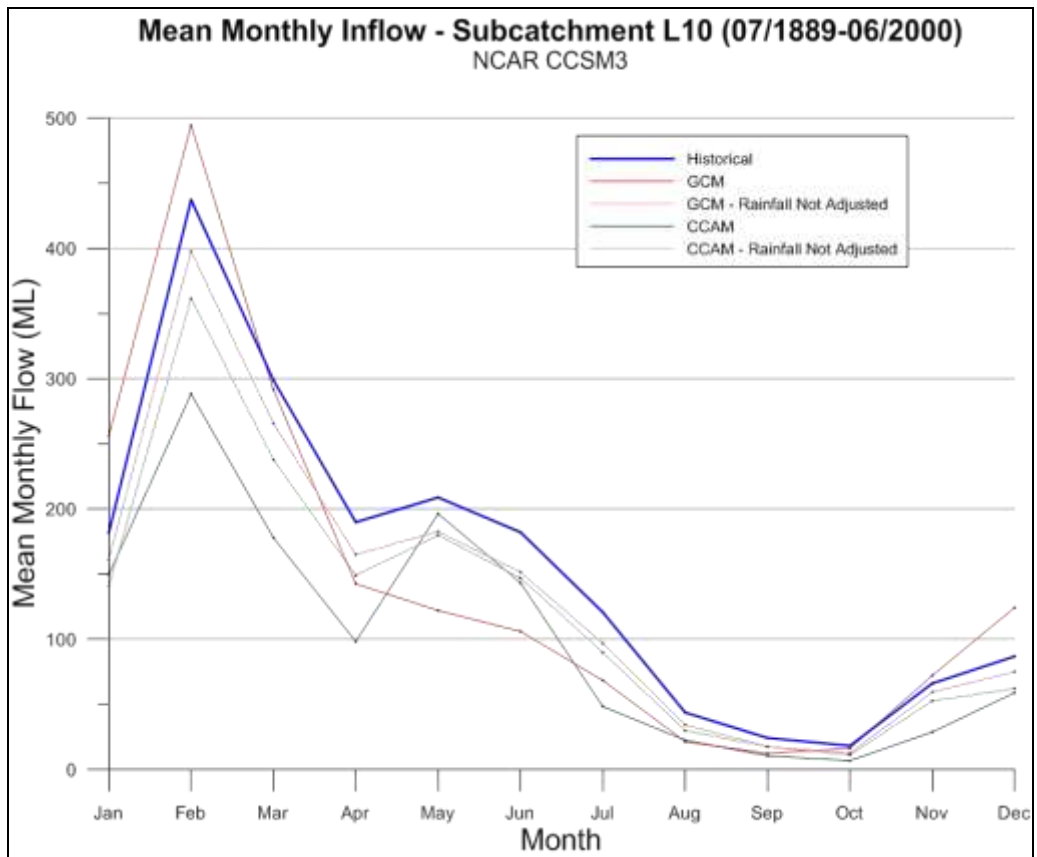


Figure F.34 Mean monthly climate change inflow – comparison of generation methods for NCAR CCSM3 (GCM and CCAM) – Subarea L10.

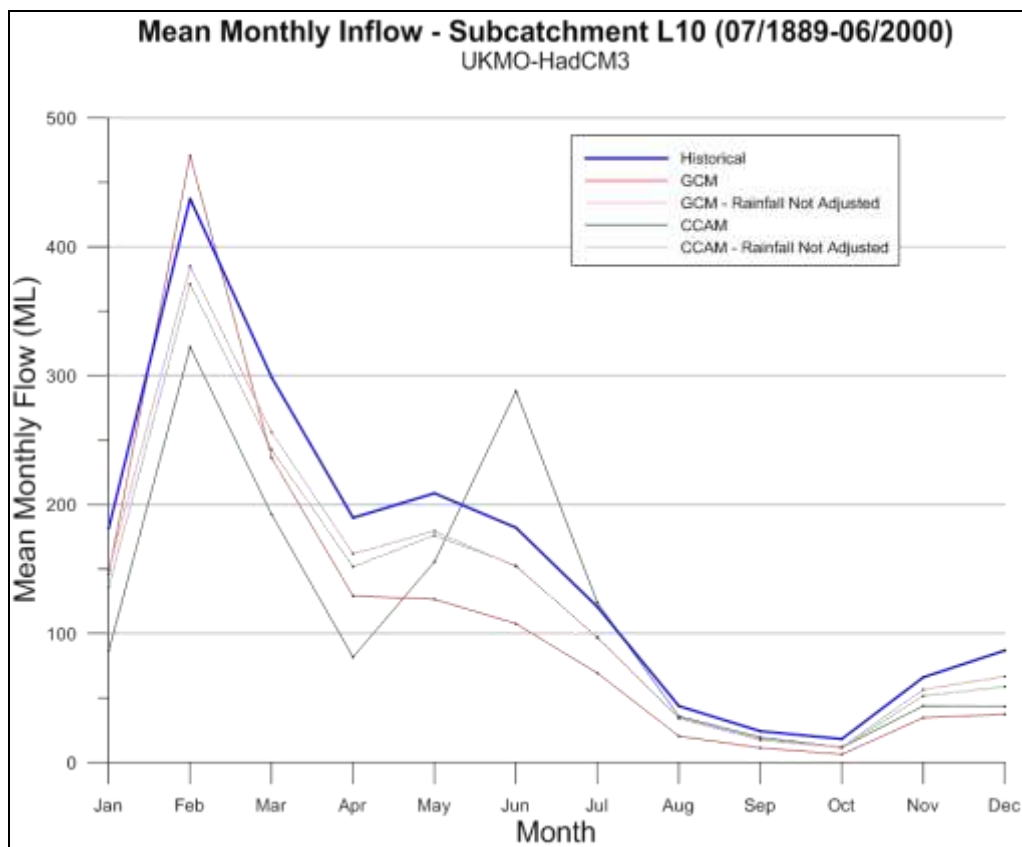


Figure F.35 Mean monthly climate change inflow – comparison of generation methods for UKMO HadCM3 (GCM and CCAM) – Subarea L10.

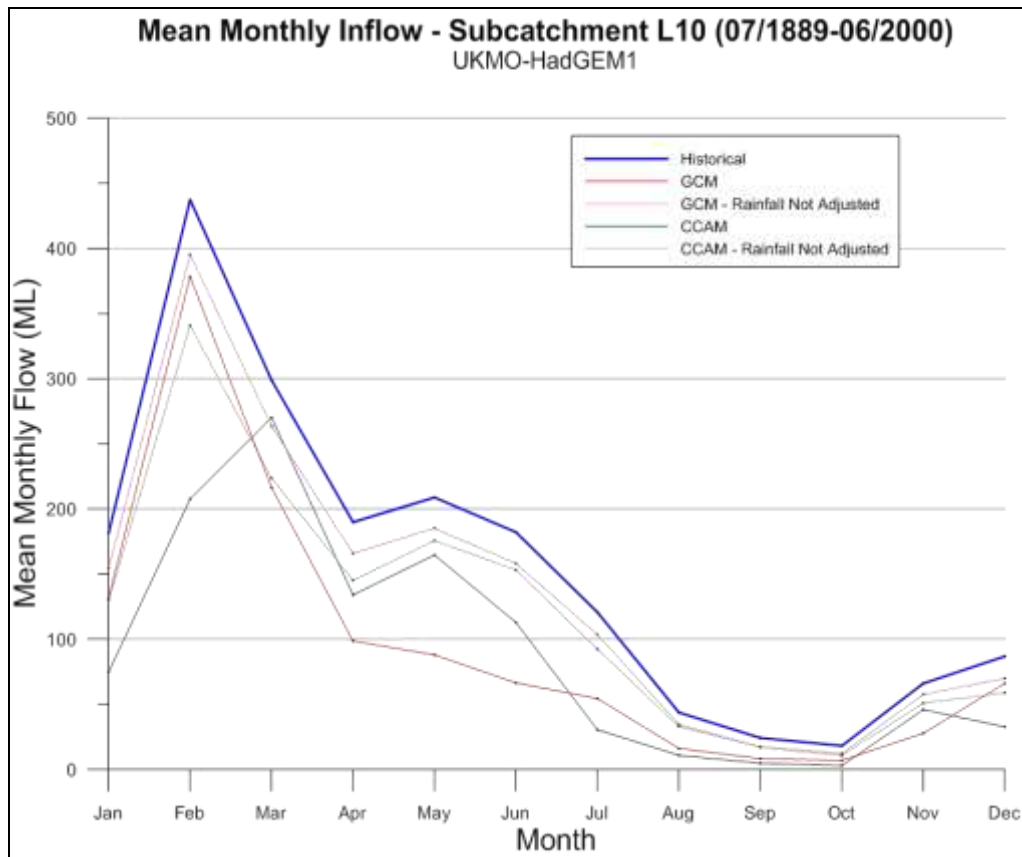


Figure F.36 Mean monthly climate change inflow – comparison of generation methods for UKMO HadGEM1 (GCM and CCAM) – Subarea L10.

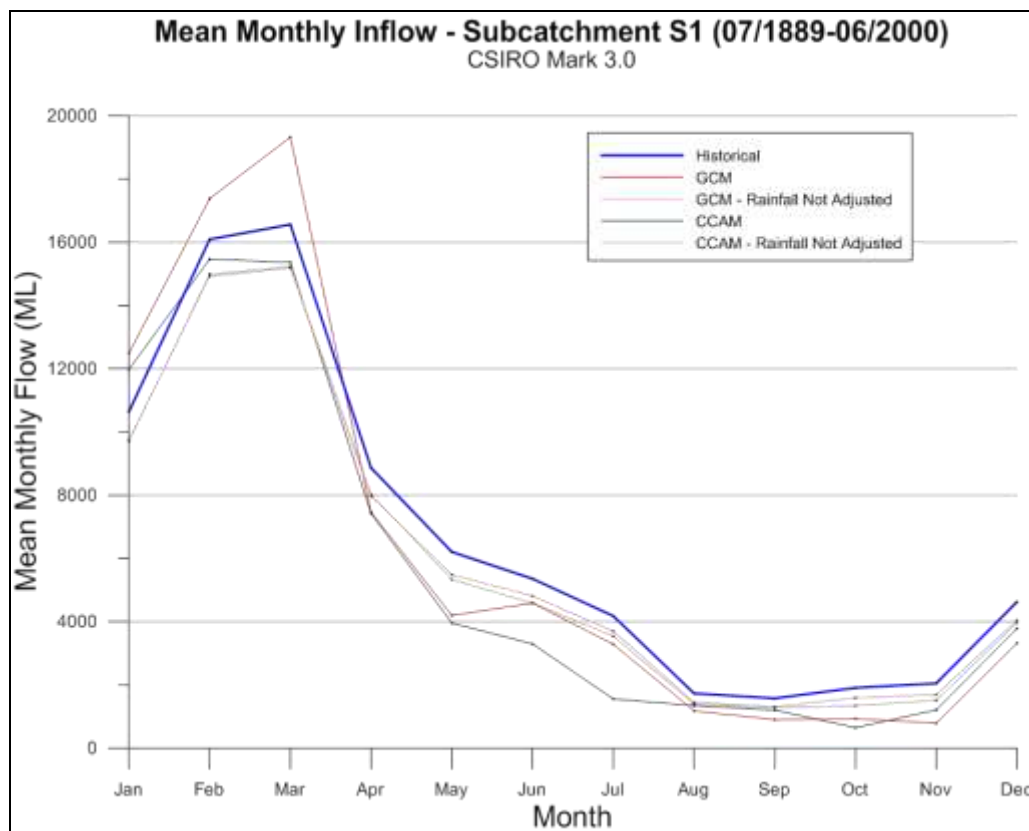


Figure F.37 Mean monthly climate change inflow – comparison of generation methods for CSIRO Mark 3.0 (GCM and CCAM) – Subarea S1.

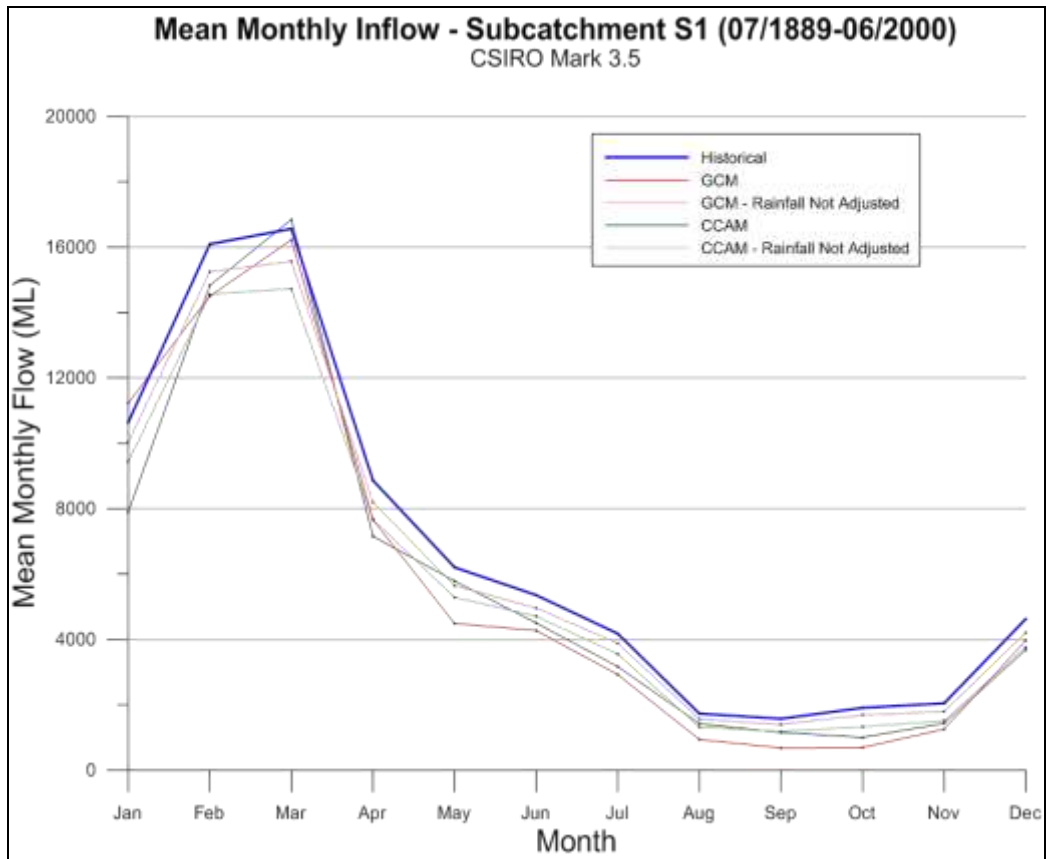


Figure F.38 Mean monthly climate change inflow – comparison of generation methods for CSIRO Mark 3.5 (GCM and CCAM) – Subarea S1.

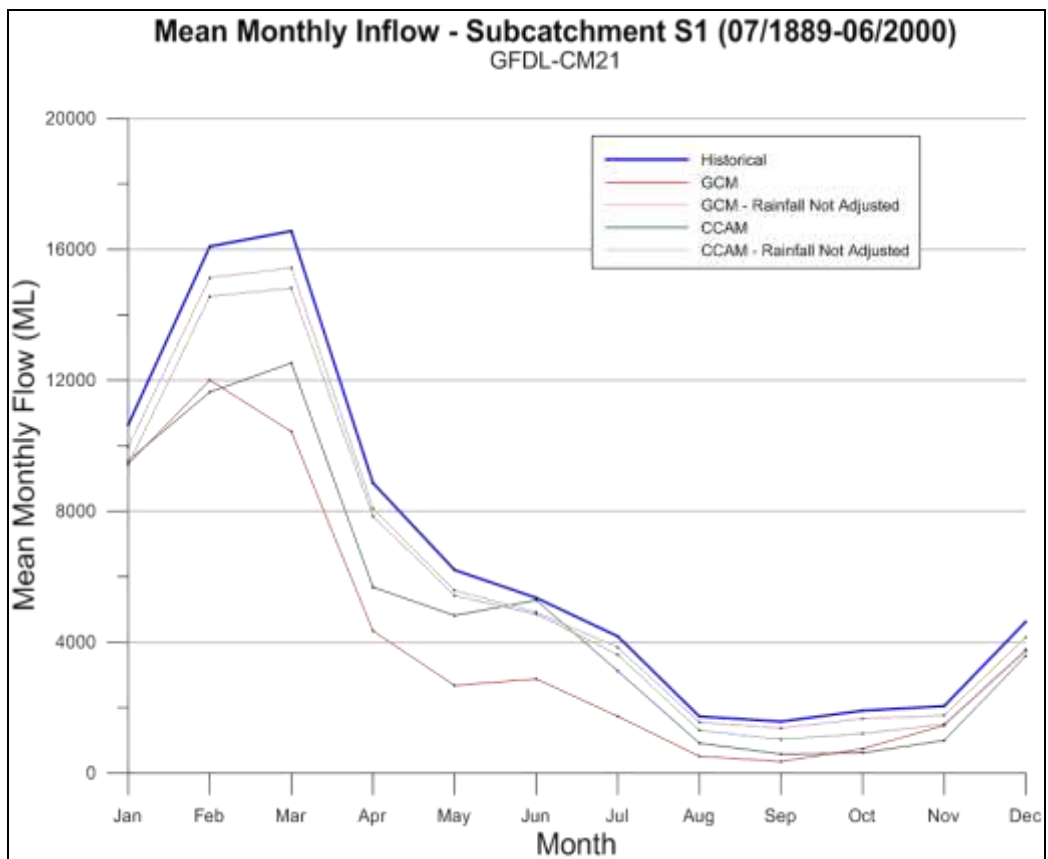


Figure F.39 Mean monthly climate change inflow – comparison of generation methods for GFDL CM21 (GCM and CCAM) – Subarea S1.

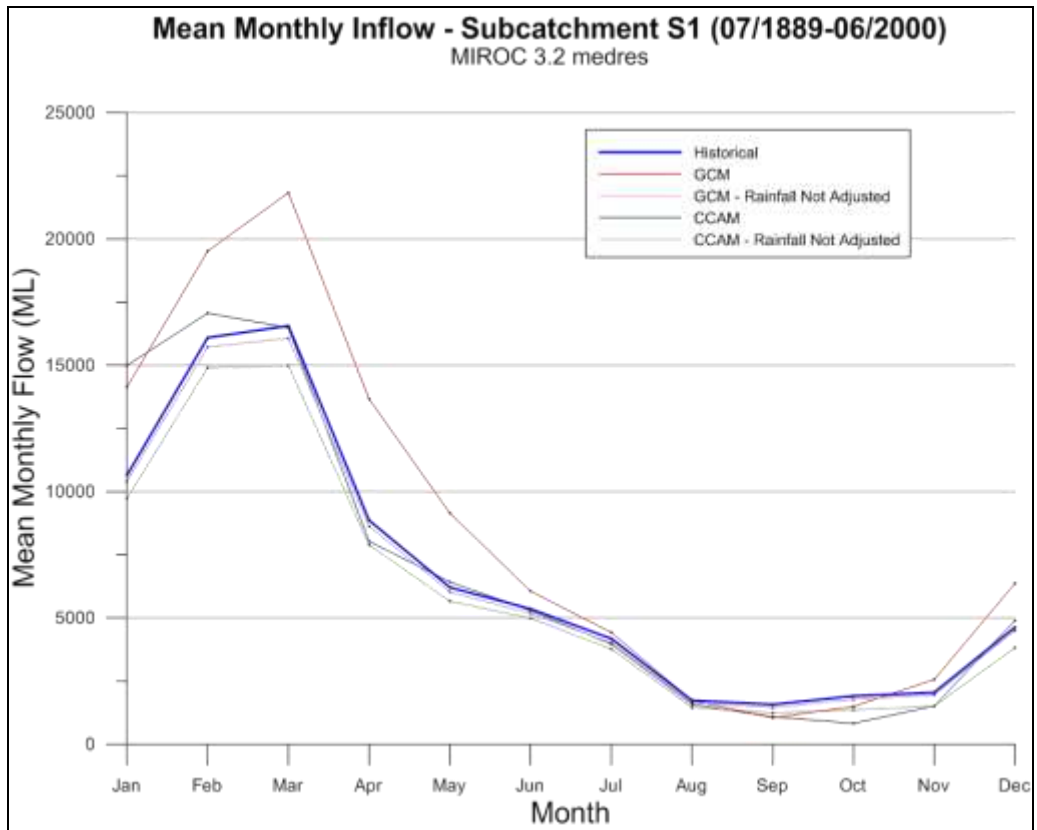


Figure F.40 Mean monthly climate change inflow – comparison of generation methods for MIROC 3.2 medres (GCM and CCAM) – Subarea S1.

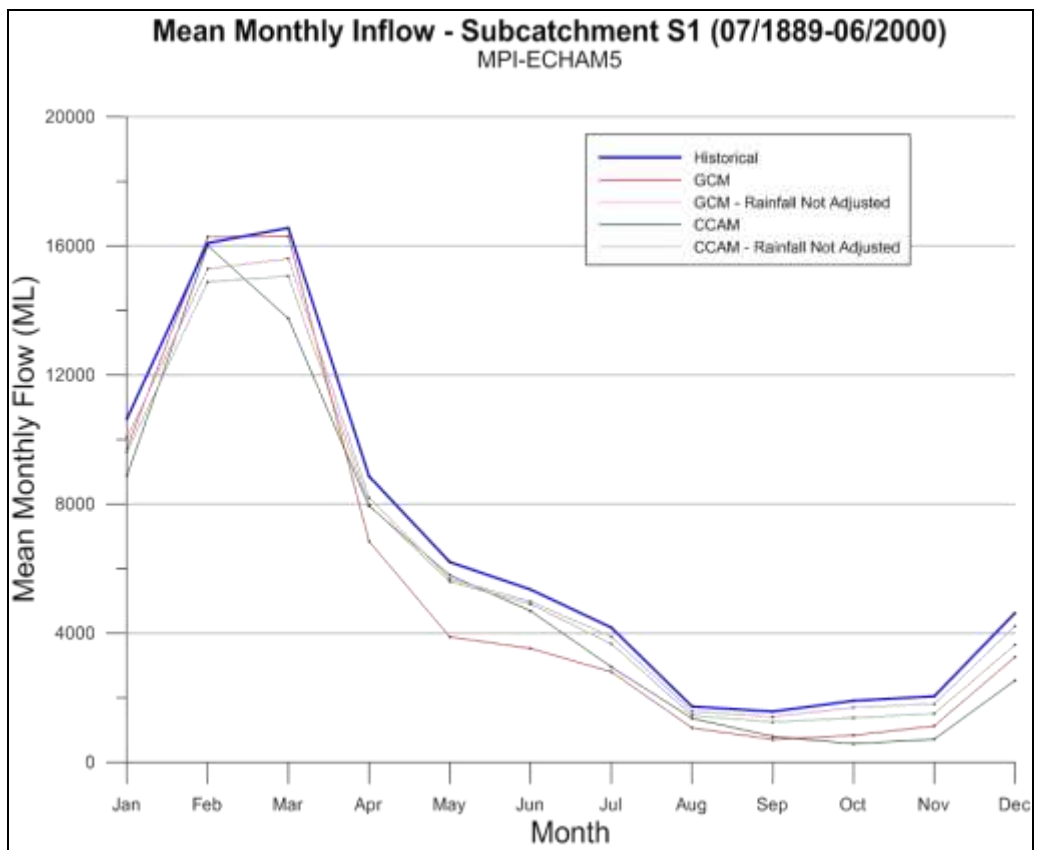


Figure F.41 Mean monthly climate change inflow – comparison of generation methods for MPI ECHAM5 (GCM and CCAM) – Subarea S1.

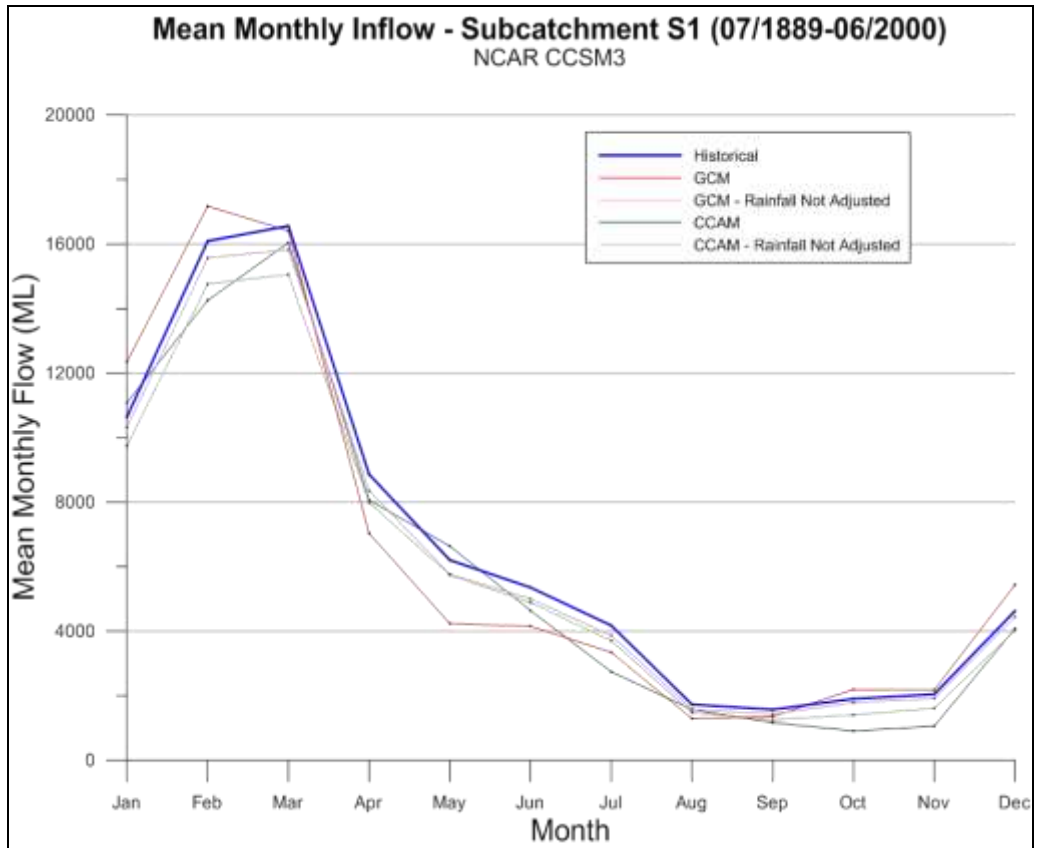


Figure F.42 Mean monthly climate change inflow – comparison of generation methods for NCAR CCSM3 (GCM and CCAM) – Subarea S1.

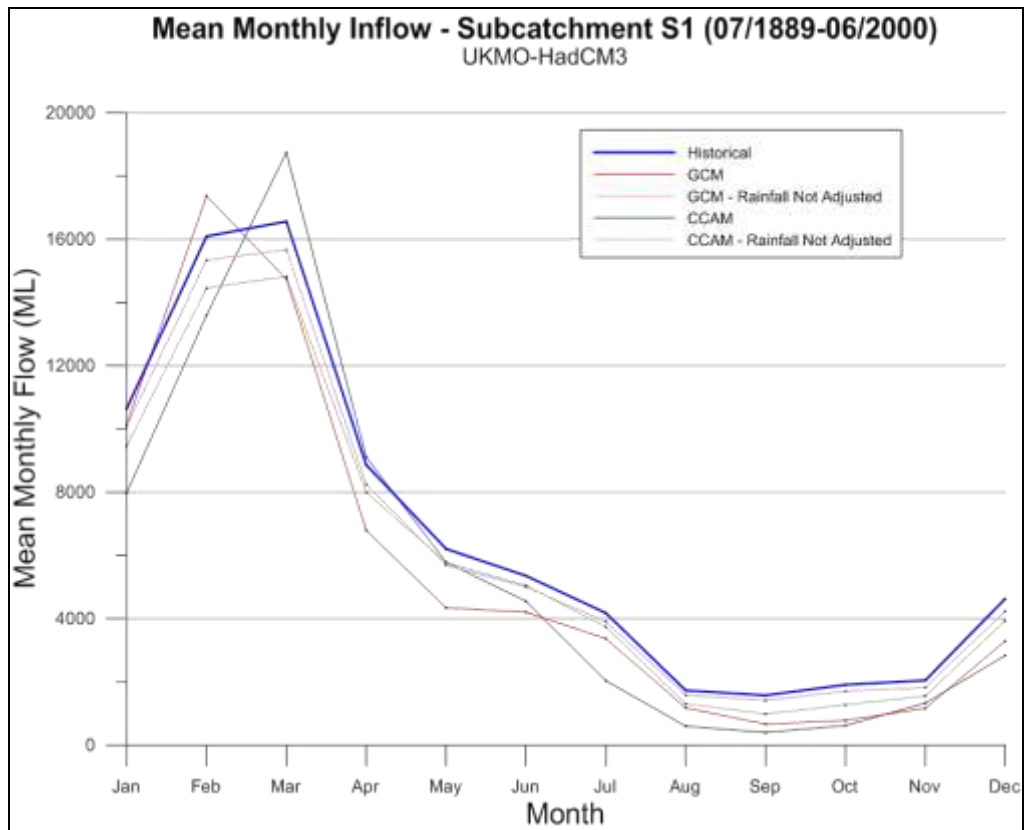


Figure F.43 Mean monthly climate change inflow – comparison of generation methods for UKMO HadCM3 (GCM and CCAM) – Subarea S1.

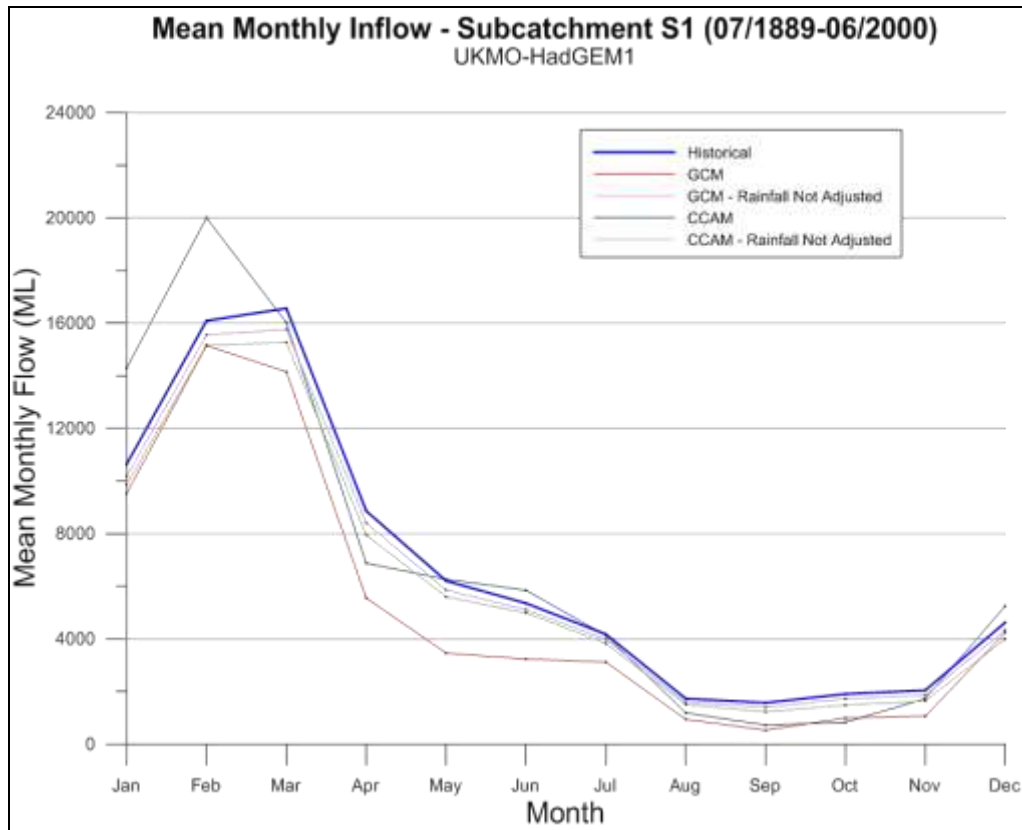


Figure F.44 Mean monthly climate change inflow – comparison of generation methods for UKMO HadGEM1 (GCM and CCAM) – Subarea S1.

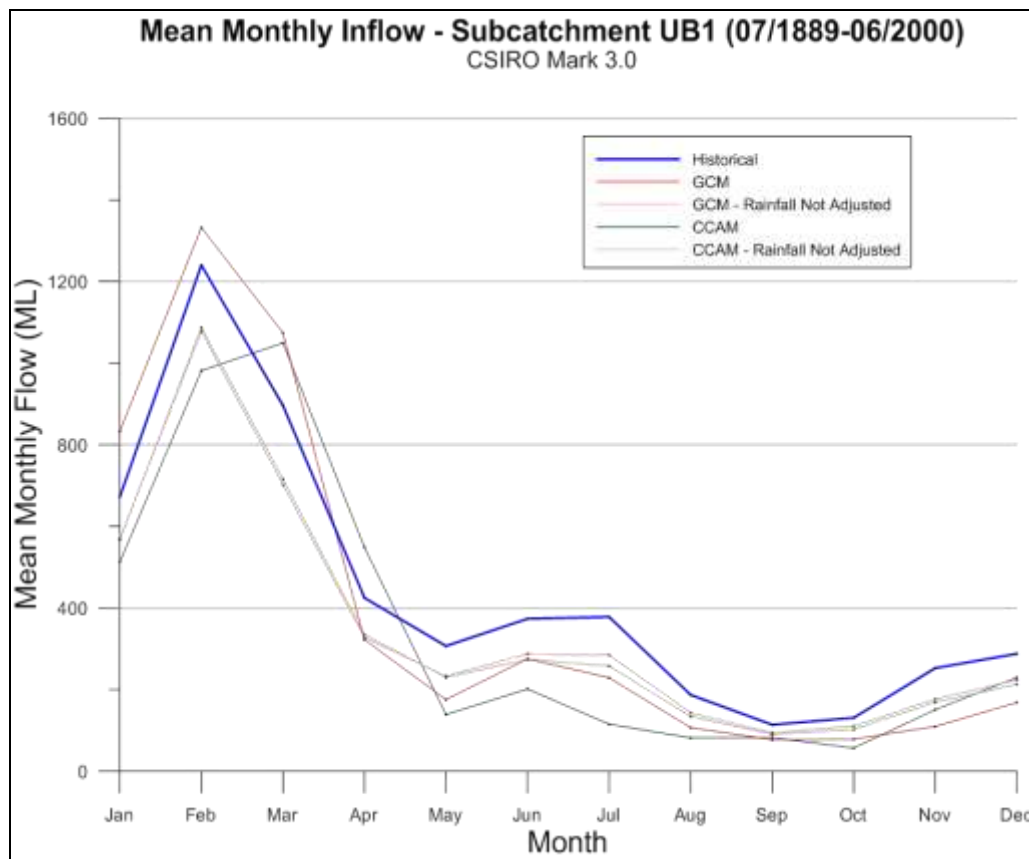


Figure F.45 Mean monthly climate change inflow – comparison of generation methods for CSIRO Mark 3.0 (GCM and CCAM) – Subarea UB1.

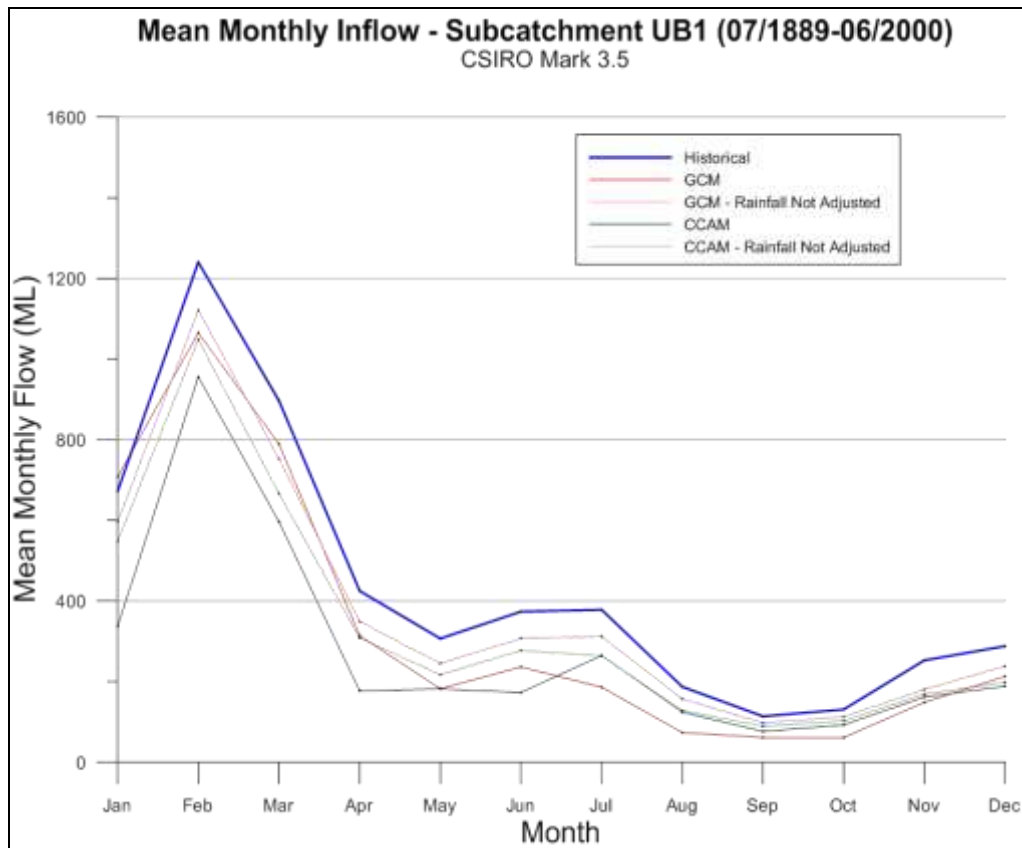


Figure F.46 Mean monthly climate change inflow – comparison of generation methods for CSIRO Mark 3.5 (GCM and CCAM) – Subarea UB1.

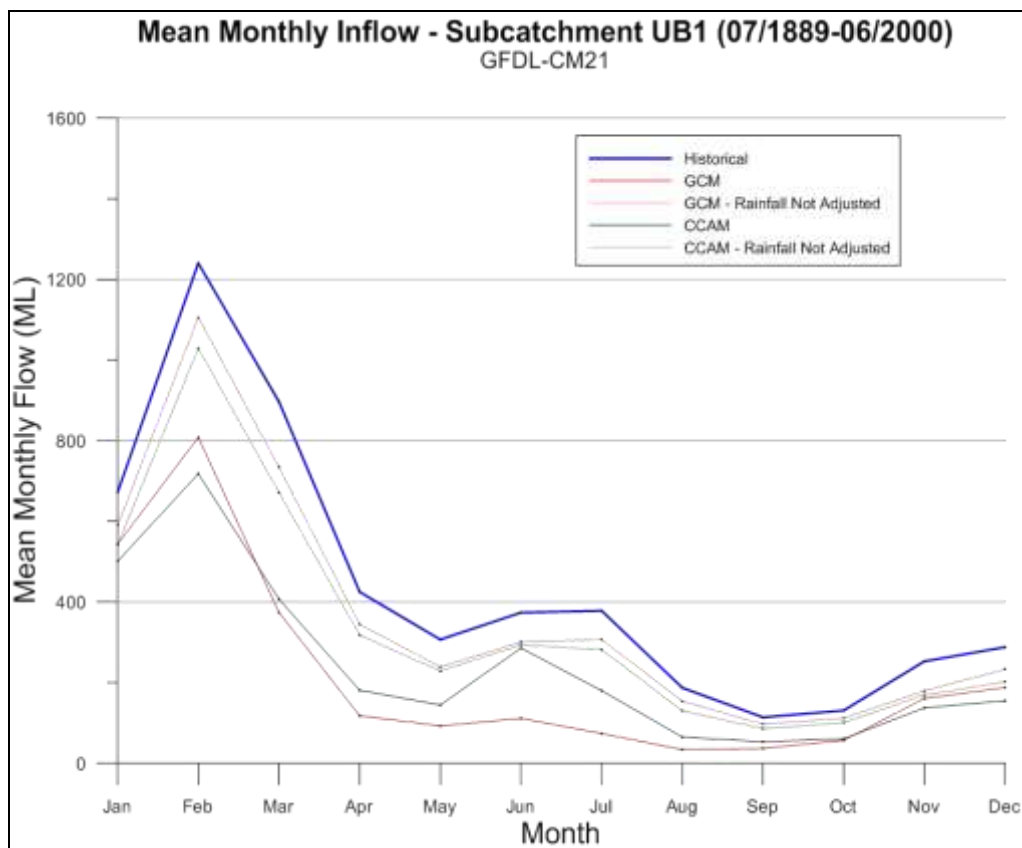


Figure F.47 Mean monthly climate change inflow – comparison of generation methods for GFDL CM21 (GCM and CCAM) – Subarea UB1.

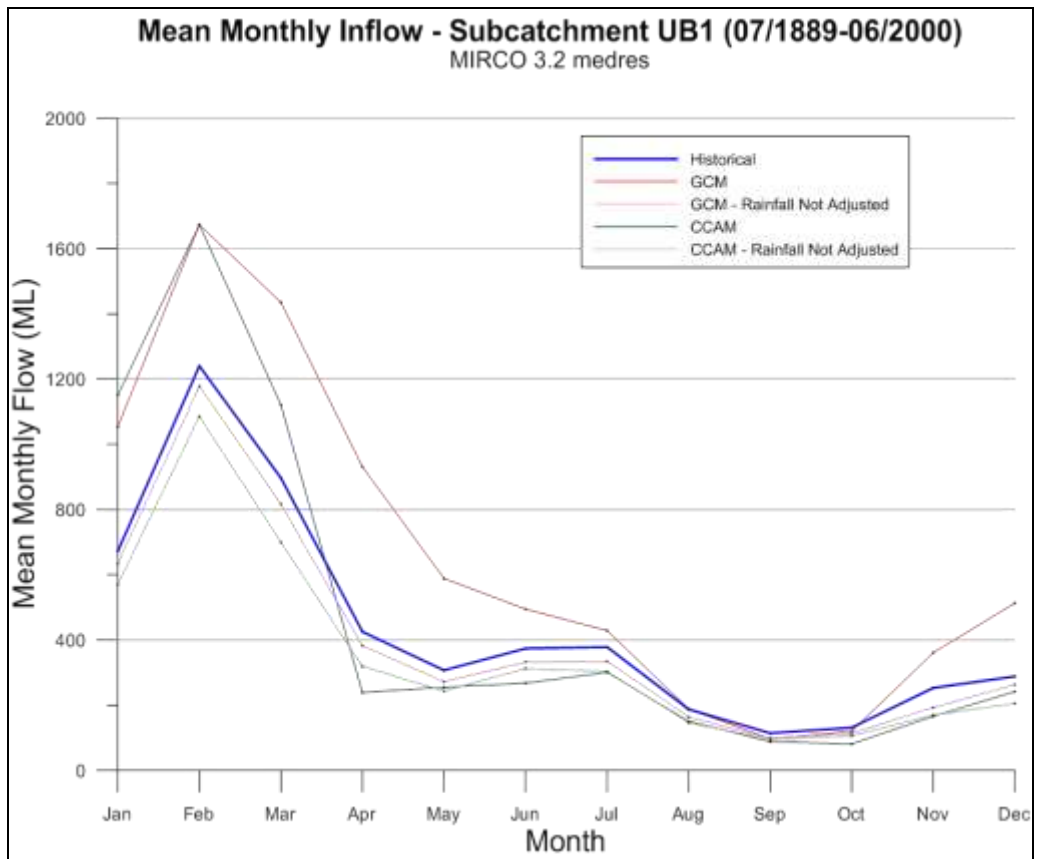


Figure F.48 Mean monthly climate change inflow – comparison of generation methods for MIROC 3.2 medres (GCM and CCAM) – Subarea UB1.

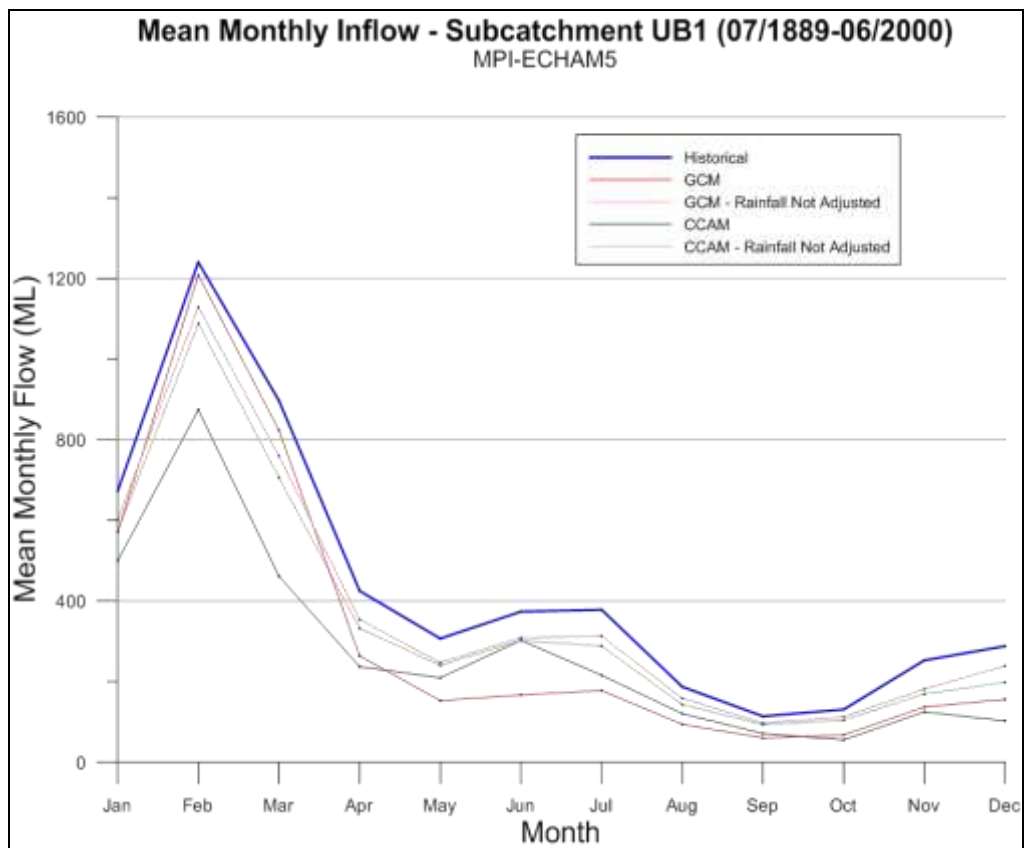


Figure F.49 Mean monthly climate change inflow – comparison of generation methods for MPI ECHAM5 (GCM and CCAM) – Subarea UB1.

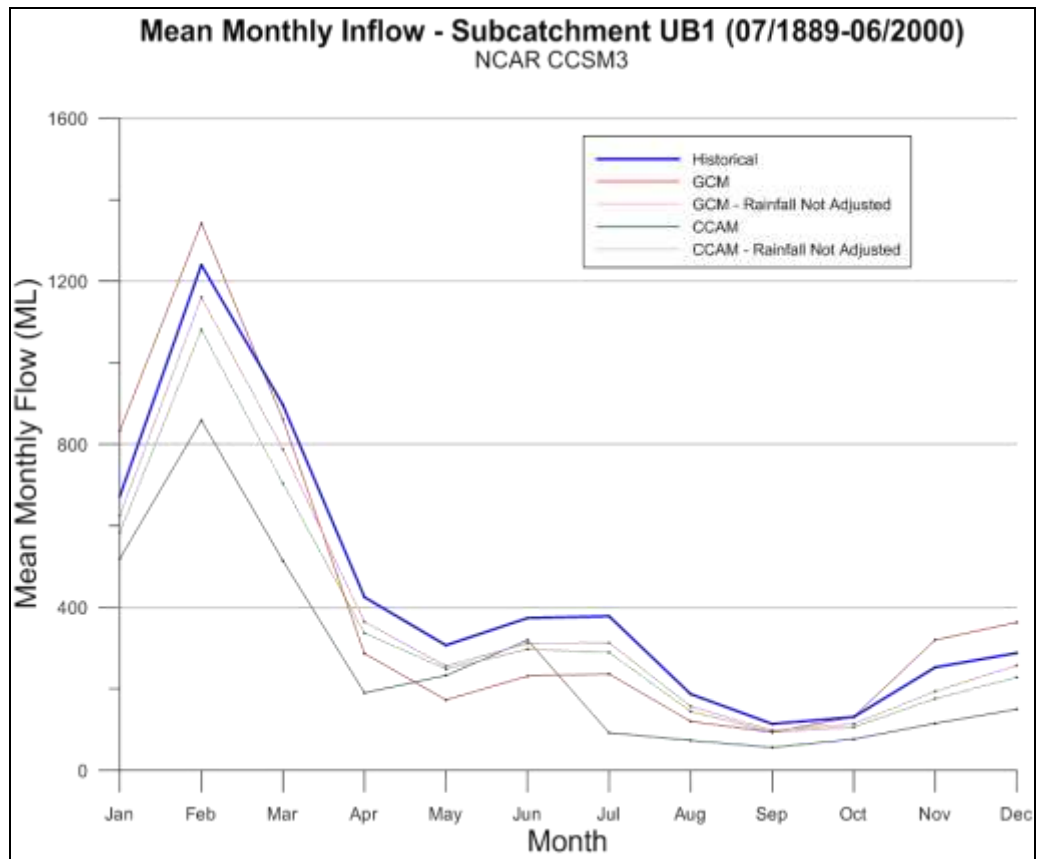


Figure F.50 Mean monthly climate change inflow – comparison of generation methods for NCAR CCSM3 (GCM and CCAM) – Subarea UB1.

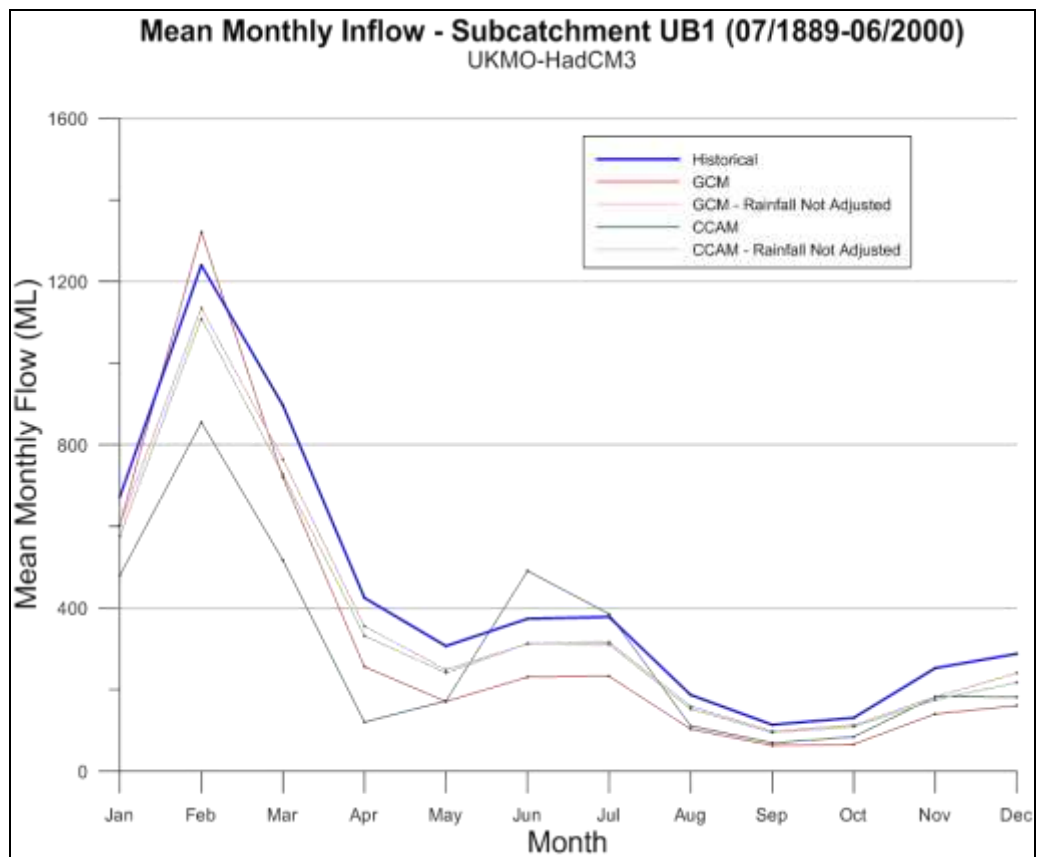


Figure F.51 Mean monthly climate change inflow – comparison of generation methods for UKMO HadCM3 (GCM and CCAM) – Subarea UB1.

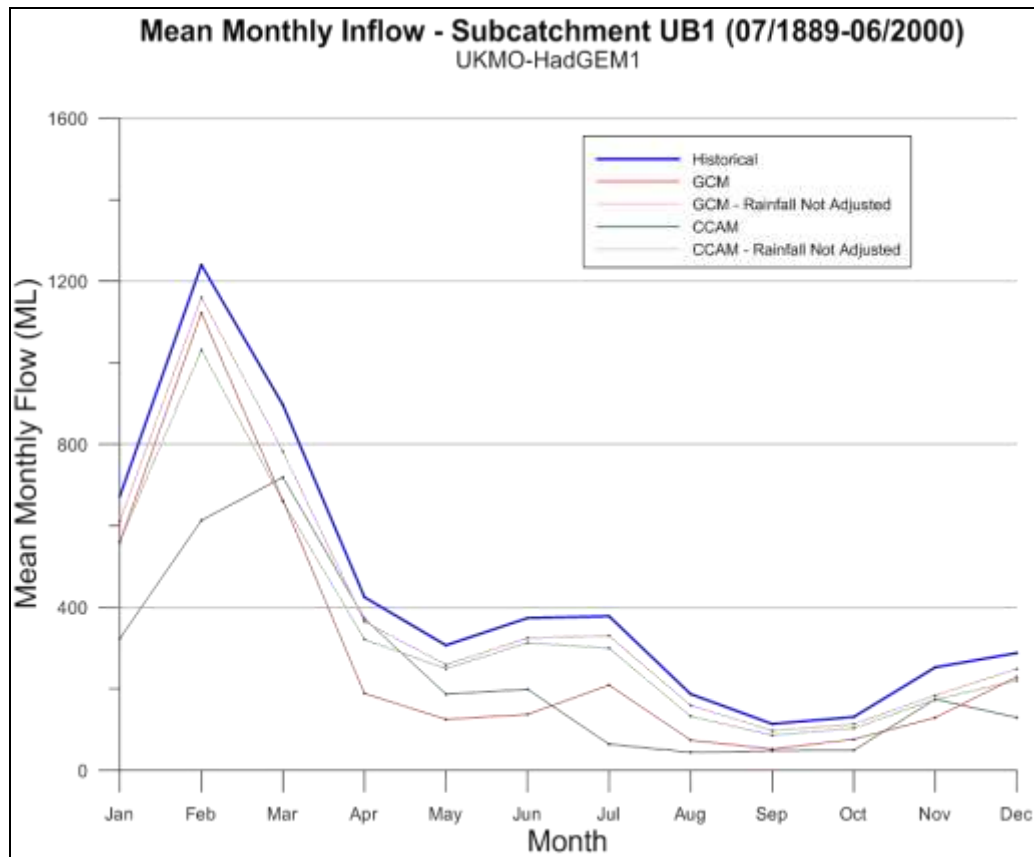


Figure F.52 Mean monthly climate change inflow – comparison of generation methods for UKMO HadGEM1 (GCM and CCAM) – Subarea UB1.

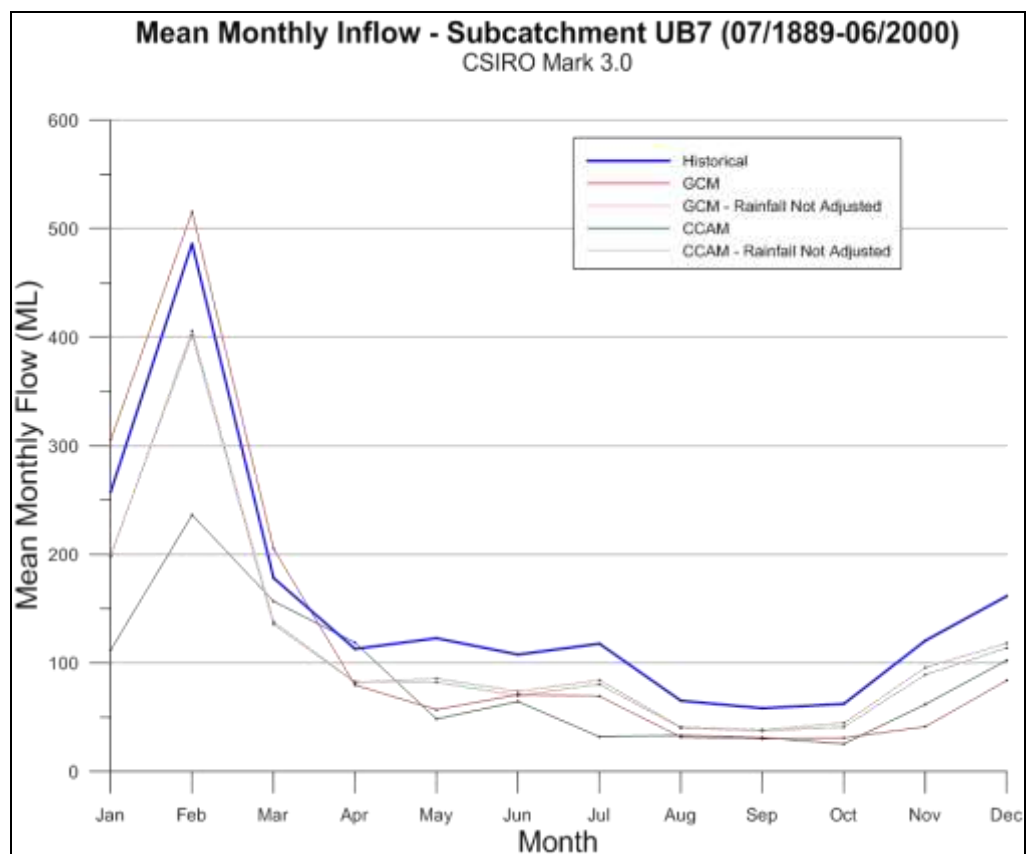


Figure F.53 Mean monthly climate change inflow – comparison of generation methods for CSIRO Mark 3.0 (GCM and CCAM) – Subarea UB7.

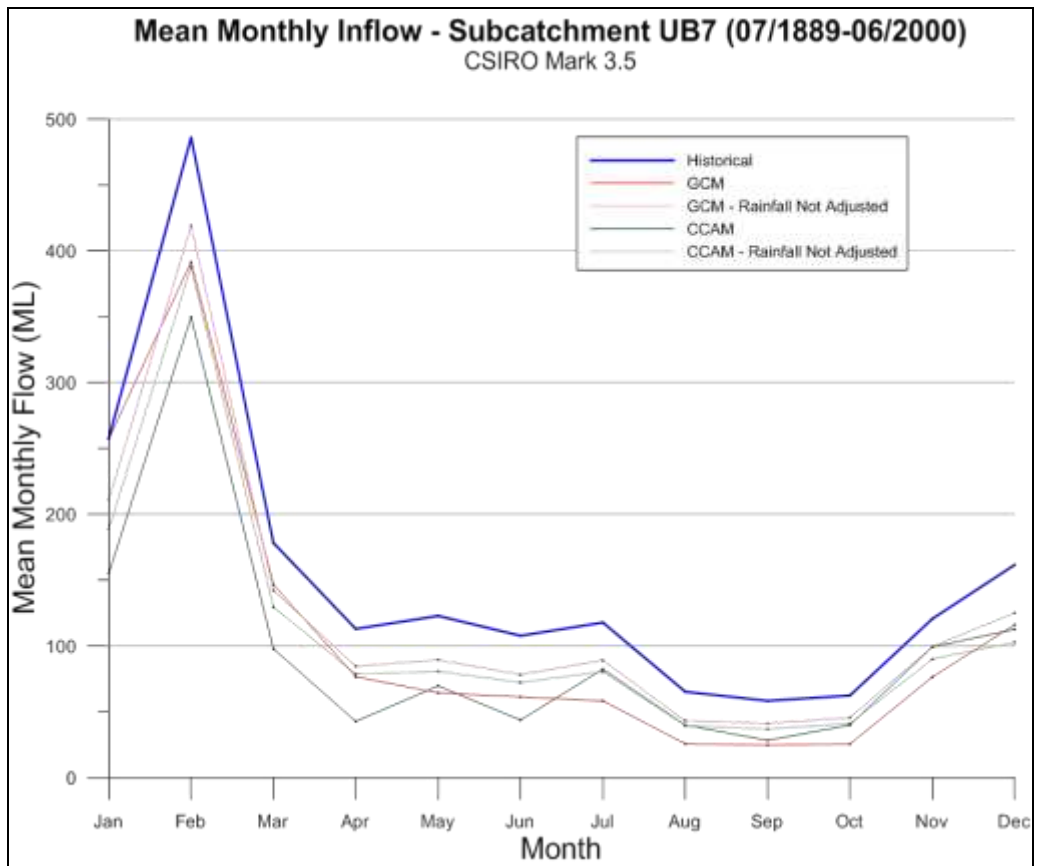


Figure F.54 Mean monthly climate change inflow – comparison of generation methods for CSIRO Mark 3.5 (GCM and CCAM) – Subarea UB7.

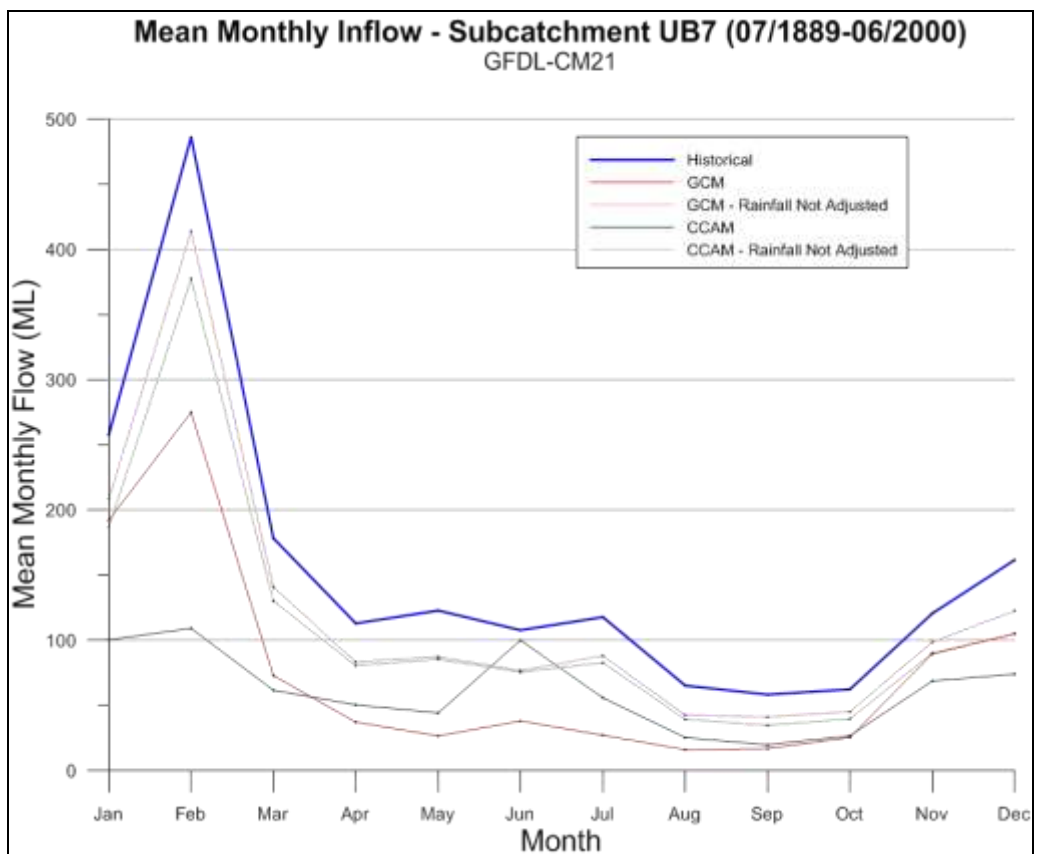


Figure F.55 Mean monthly climate change inflow – comparison of generation methods for GFDL CM21 (GCM and CCAM) – Subarea UB7.

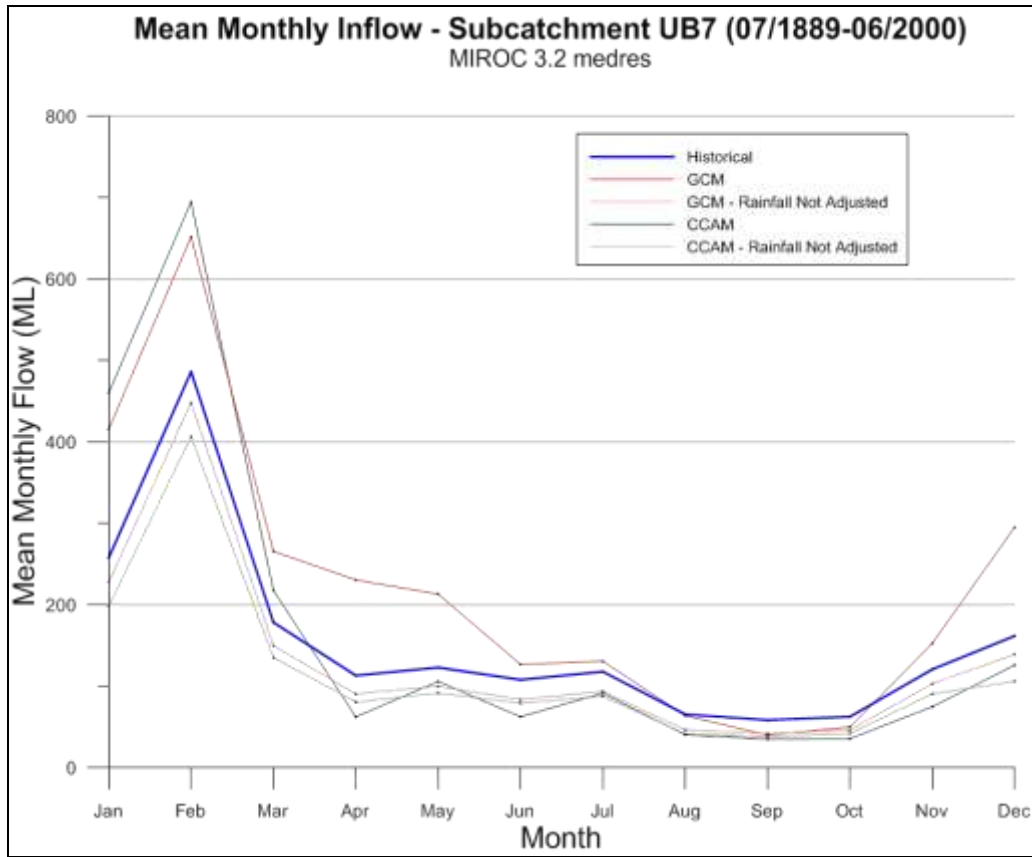


Figure F.56 Mean monthly climate change inflow – comparison of generation methods for MIROC 3.2 medres (GCM and CCAM) – Subarea UB7.

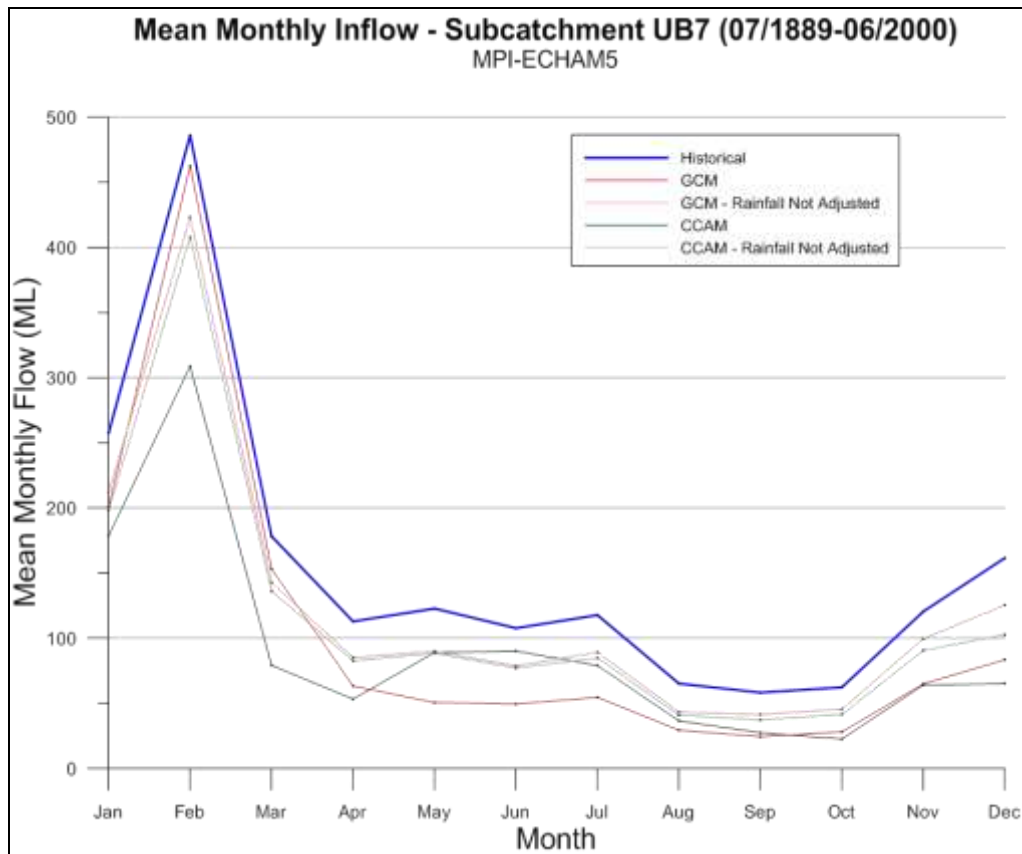


Figure F.57 Mean monthly climate change inflow – comparison of generation methods for MPI ECHAM5 (GCM and CCAM) – Subarea UB7.

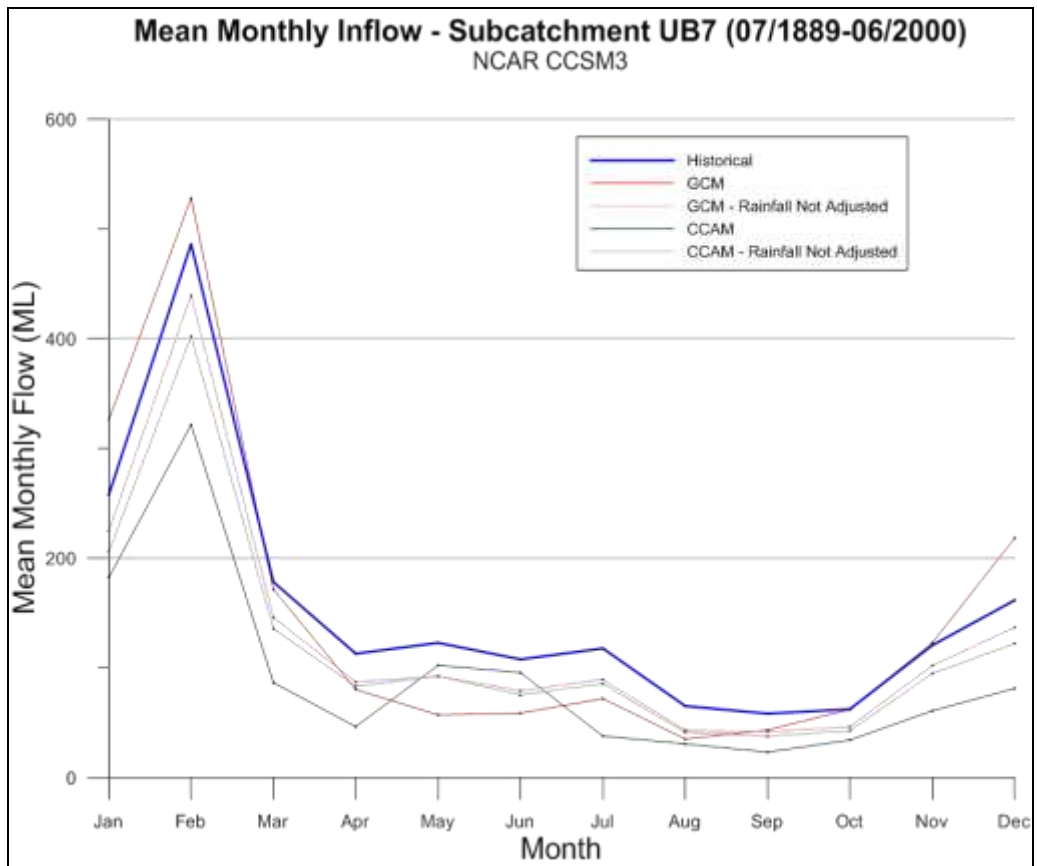


Figure F.58 Mean monthly climate change inflow – comparison of generation methods for NCAR CCSM3 (GCM and CCAM) – Subarea UB7.

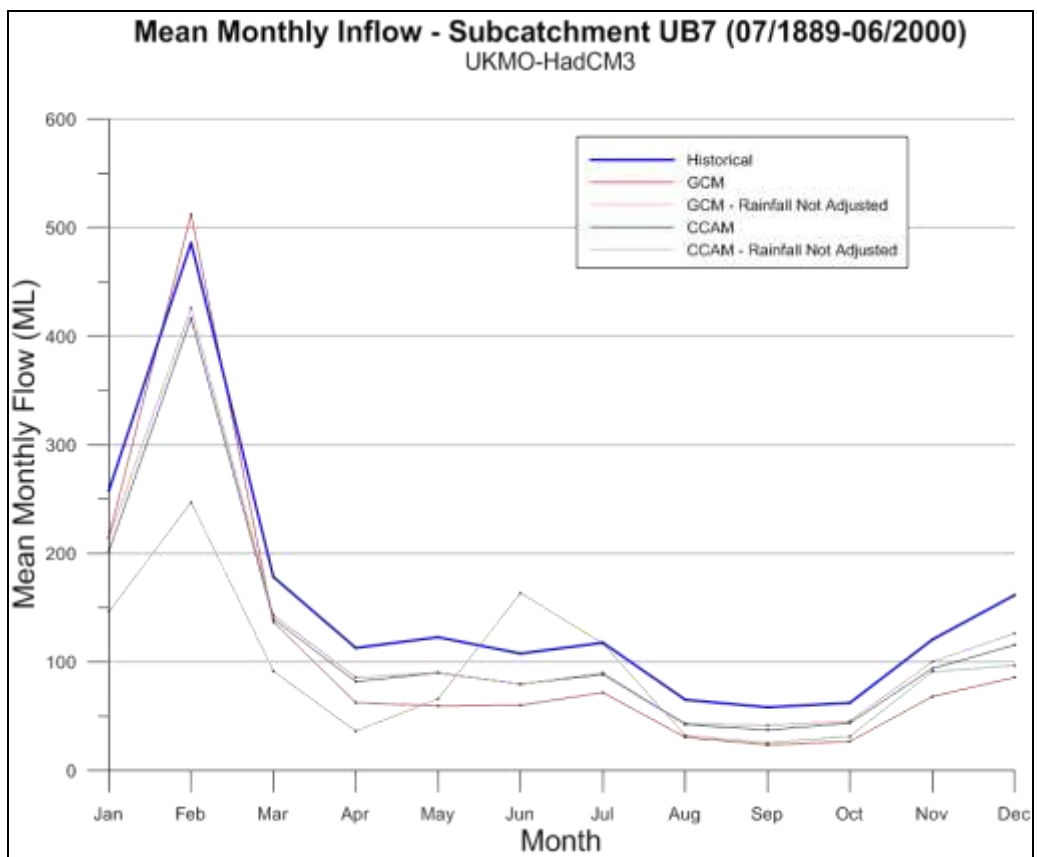


Figure F.59 Mean monthly climate change inflow – comparison of generation methods for UKMO HadCM3 (GCM and CCAM) – Subarea UB7.

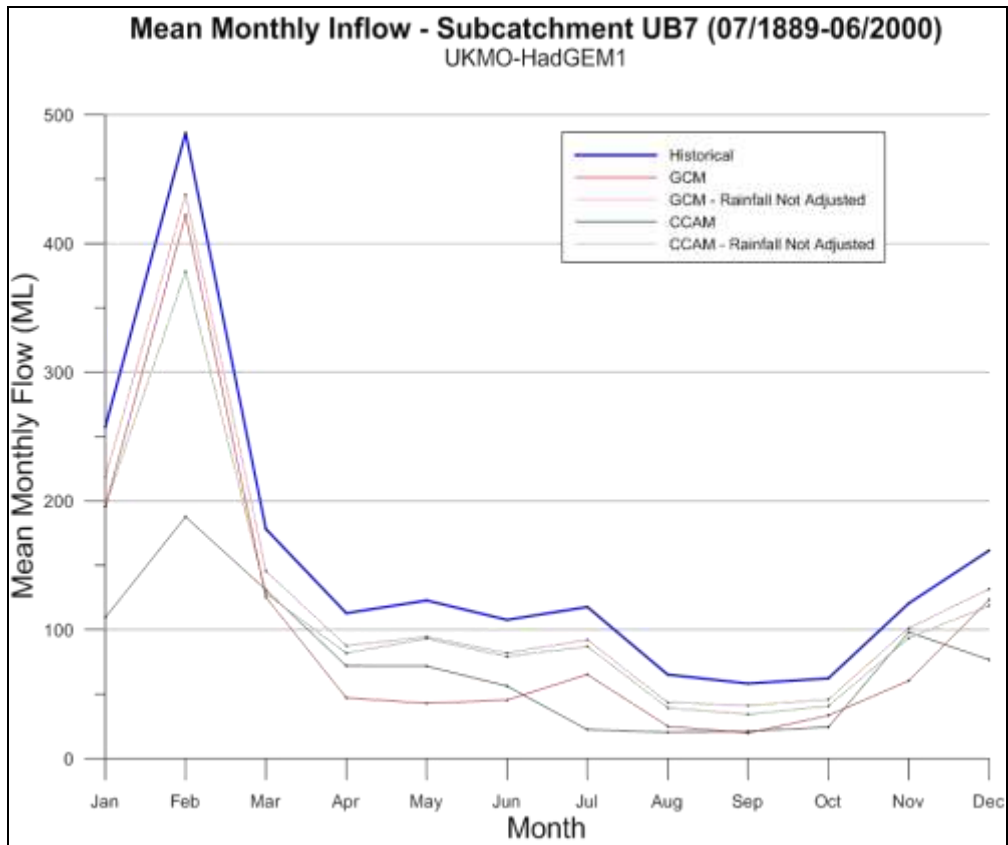


Figure F.60 Mean monthly climate change inflow – comparison of generation methods for UKMO HadGEM1 (GCM and CCAM) – Subarea UB7.

F.3.2 GCM, CCAM and CCAM PPE1

Table 7.22 Description of Relevant Generation Methods

Generation Method	Gridsize	Description
GCM	Ranging from 100 to 400km	Global circulation models developed by various research institutes around the world
CCAM	~20km	Original dynamically downscaled models using the Conformal-Cubic Atmospheric Model (CCAM) – downscaled to 20km
CCAM PPE1	~ 8km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 8km
CCAM PPE1	~20km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 20km

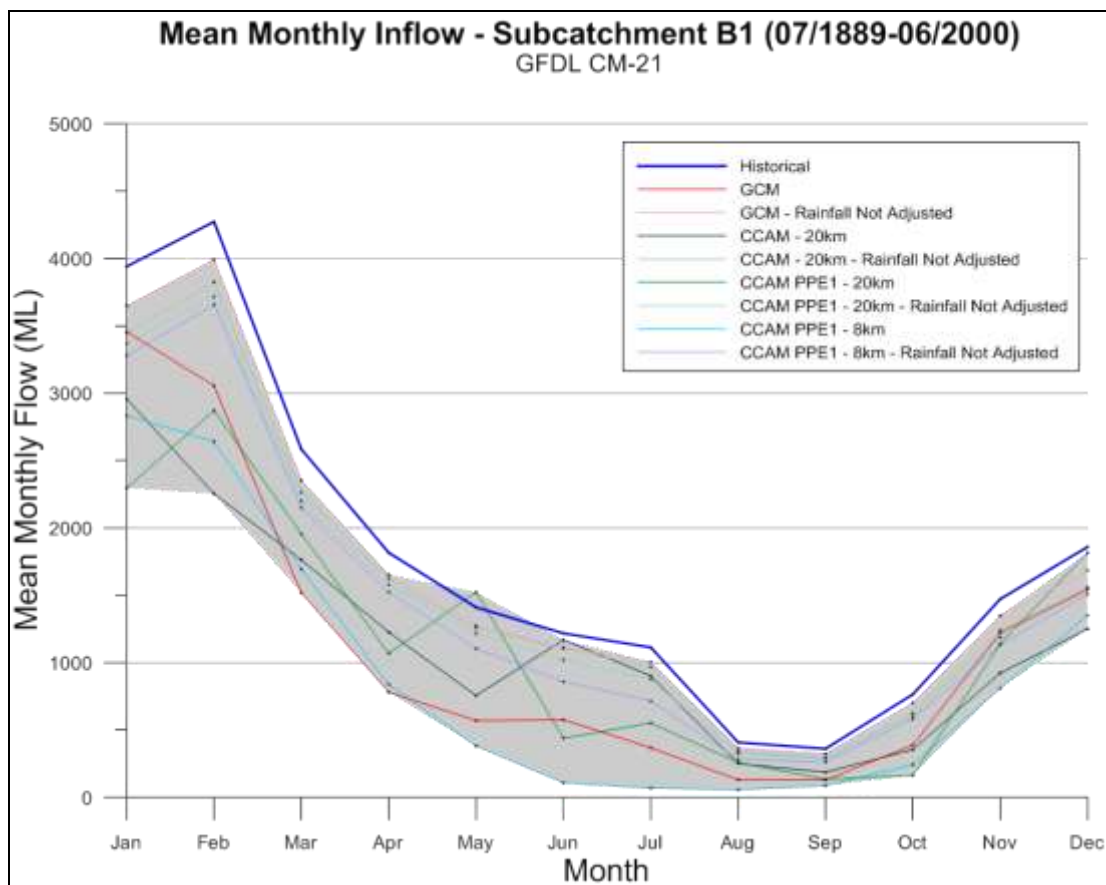


Figure F.61 Mean monthly climate change inflow – comparison of generation methods for GFDL CM21 (GCM, CCAM and CCAM PPE1) – Subarea B1 (Moogerah Dam Site).

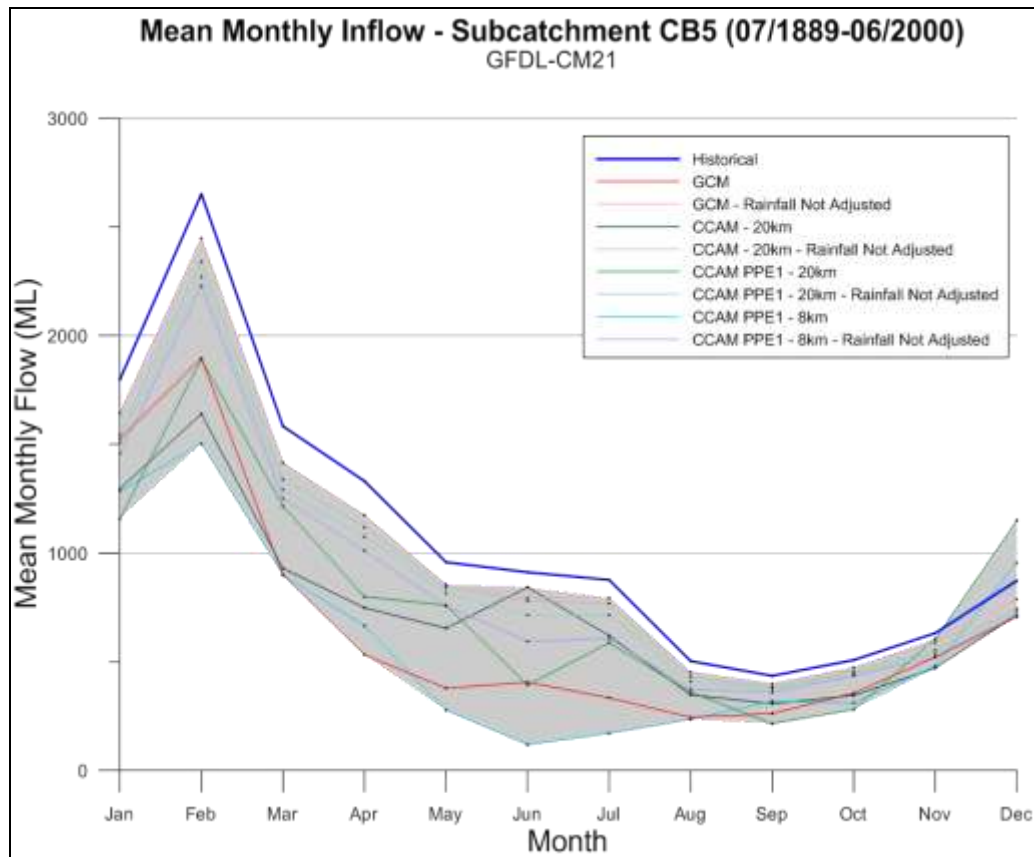


Figure F.62 Mean monthly climate change inflow – comparison of generation methods for GFDL CM21 (GCM, CCAM and CCAM PPE1) – Subarea CB5.

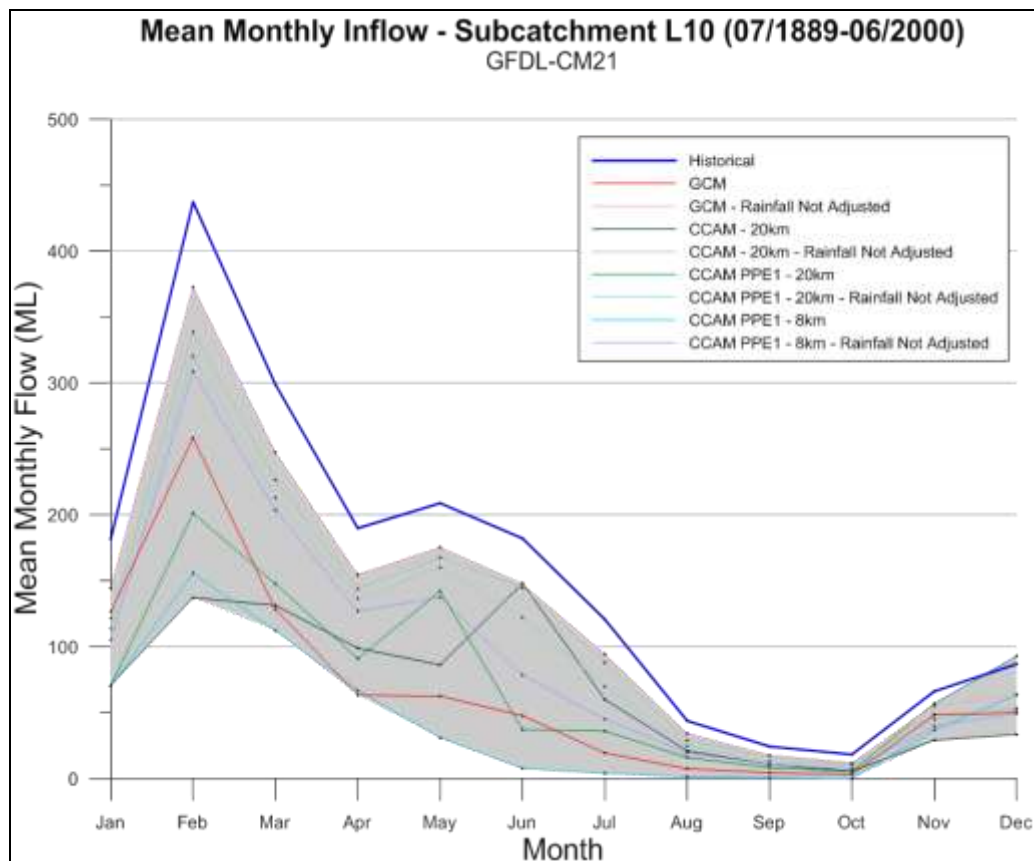


Figure F.63 Mean monthly climate change inflow – comparison of generation methods for GFDL CM21 (GCM, CCAM and CCAM PPE1) – Subarea L10.

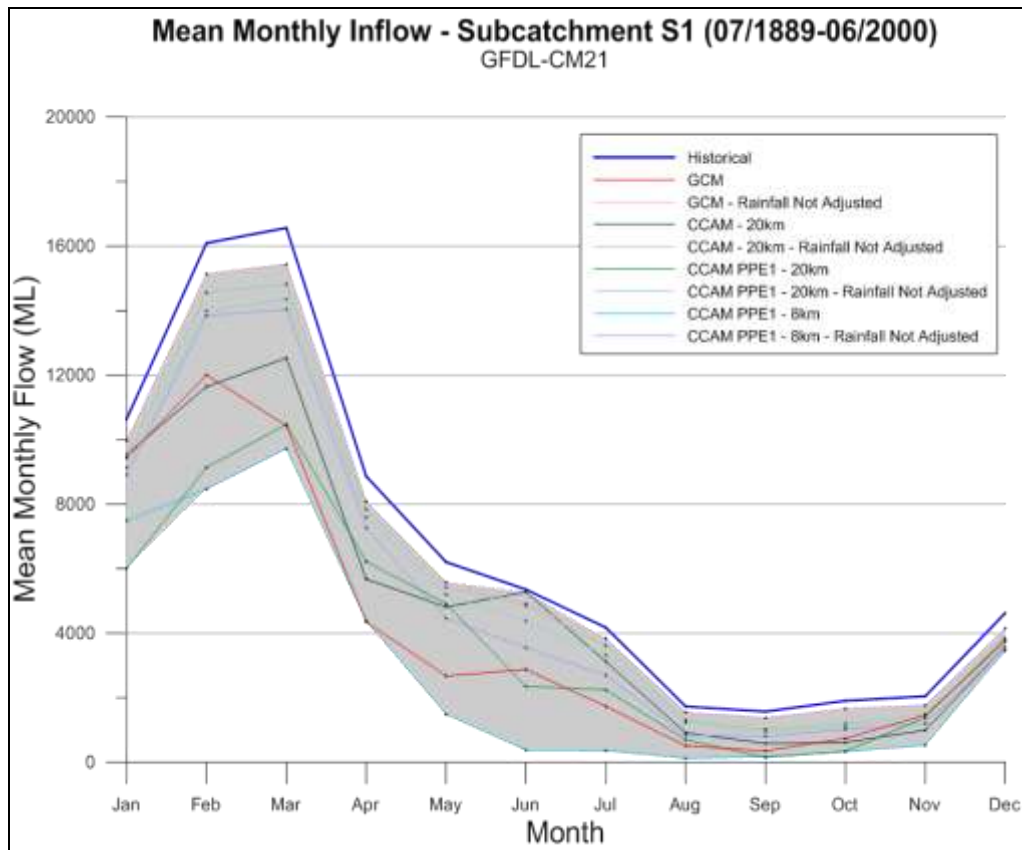


Figure F.64 Mean monthly climate change inflow – comparison of generation methods for GFDL CM21 (GCM, CCAM and CCAM PPE1) – Subarea S1.

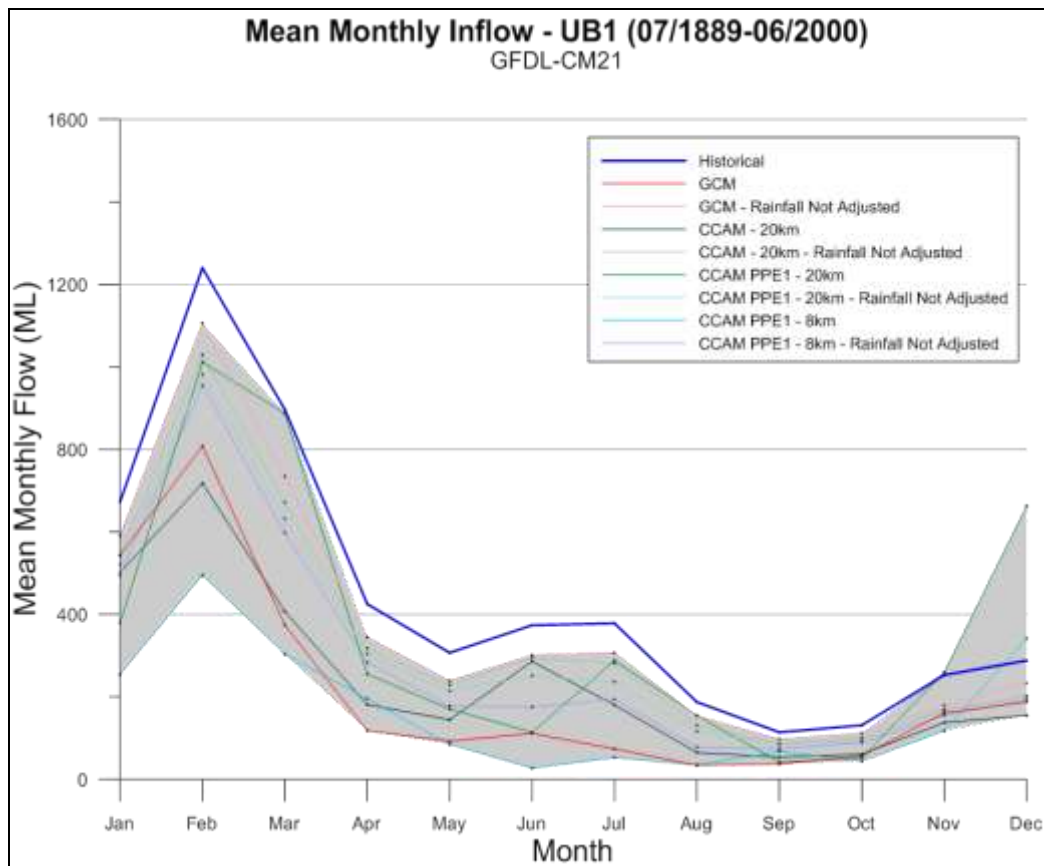


Figure F.65 Mean monthly climate change inflow – comparison of generation methods for GFDL CM21 (GCM, CCAM and CCAM PPE1) – Subarea UB1.

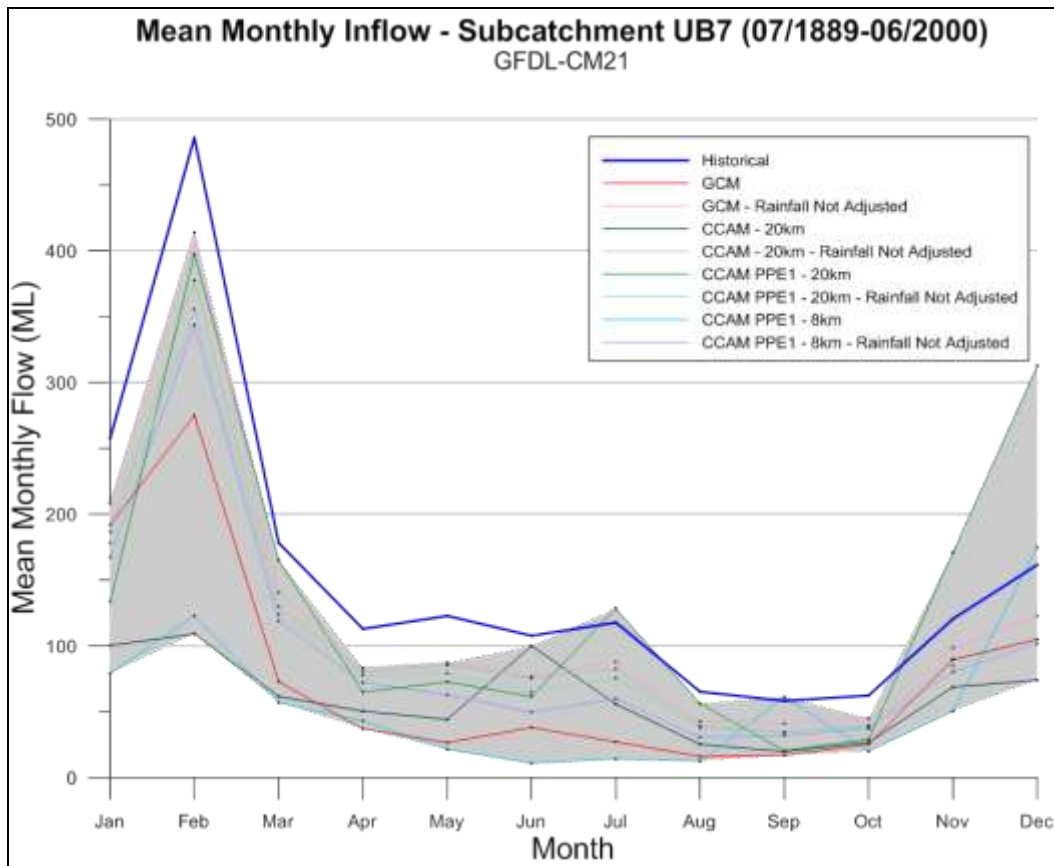


Figure F.66 Mean monthly climate change inflow – comparison of generation methods for GFDL CM21 (GCM, CCAM and CCAM PPE1) – Subarea UB7.

APPENDIX G Climate Change Model Output – Storage Curves

G.1 Global Circulation Model Method

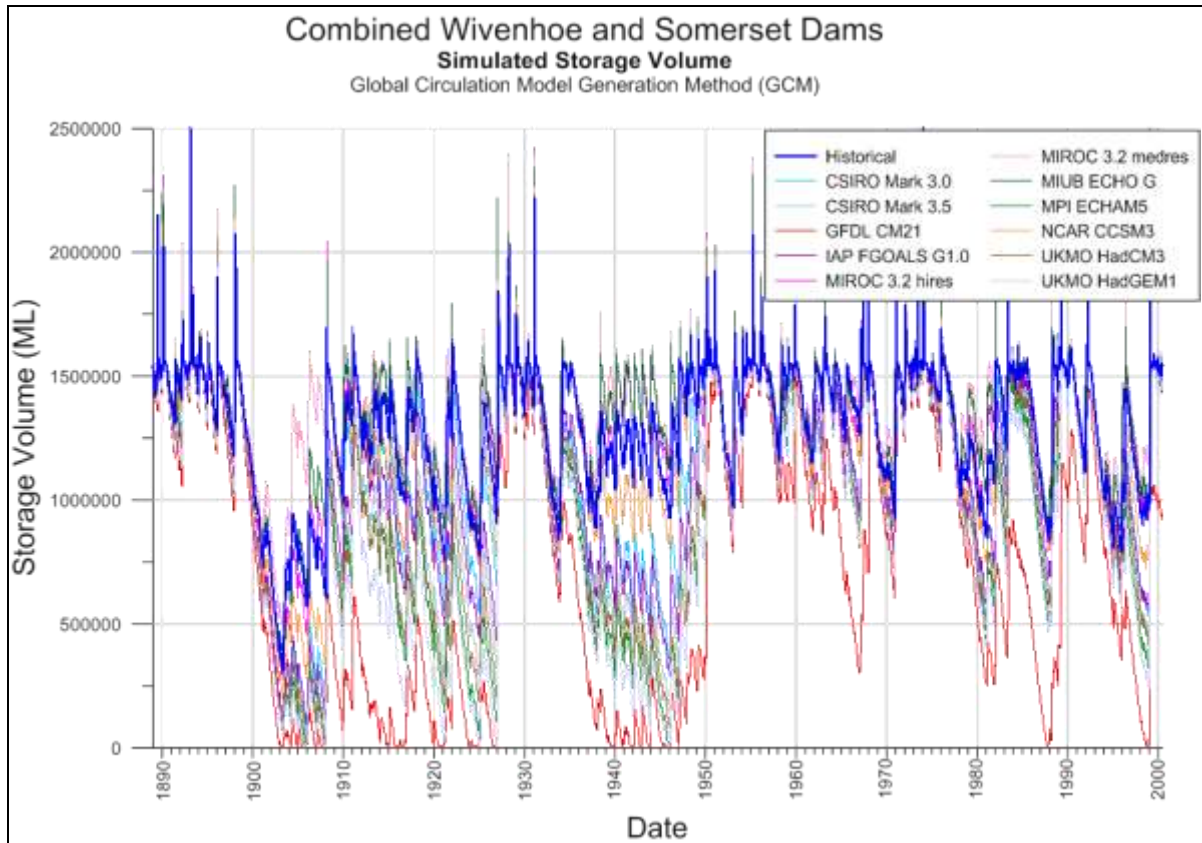


Figure G.1 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and GCM Climate Models.

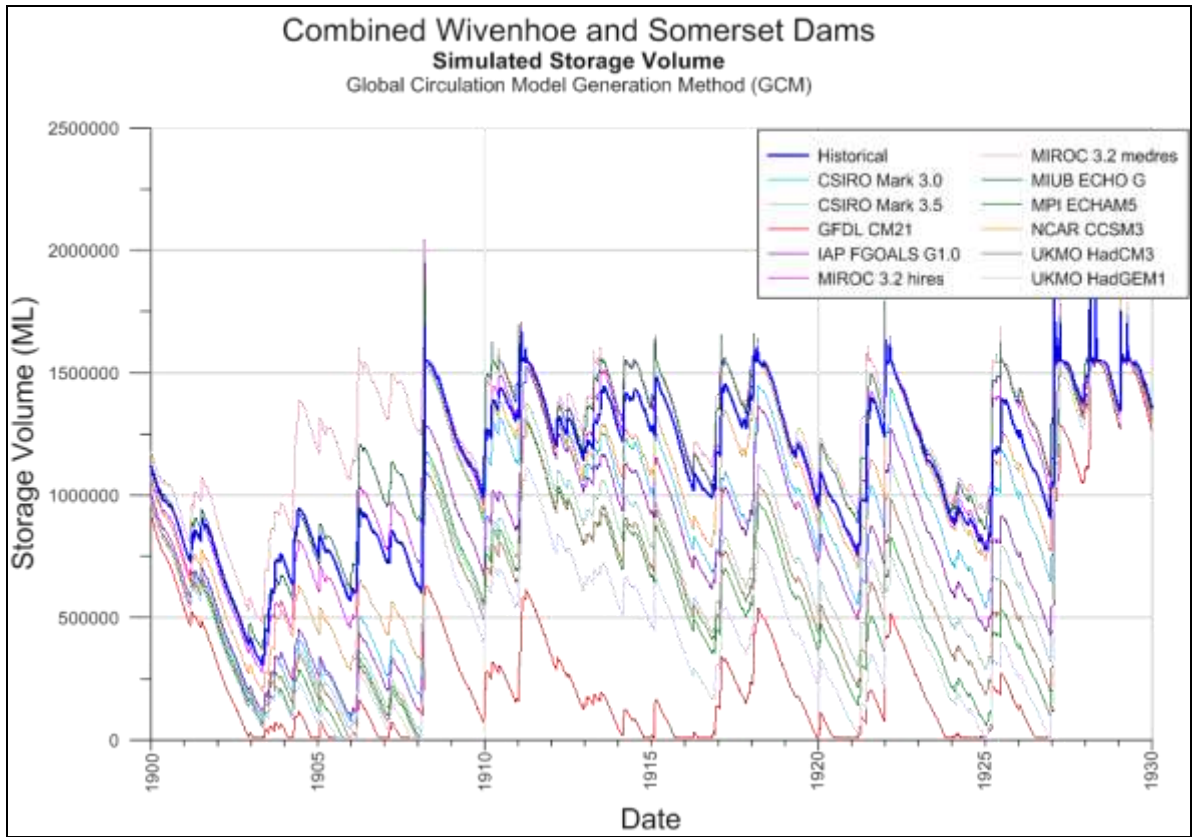


Figure G.2 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and GCM Climate Models (zoomed).

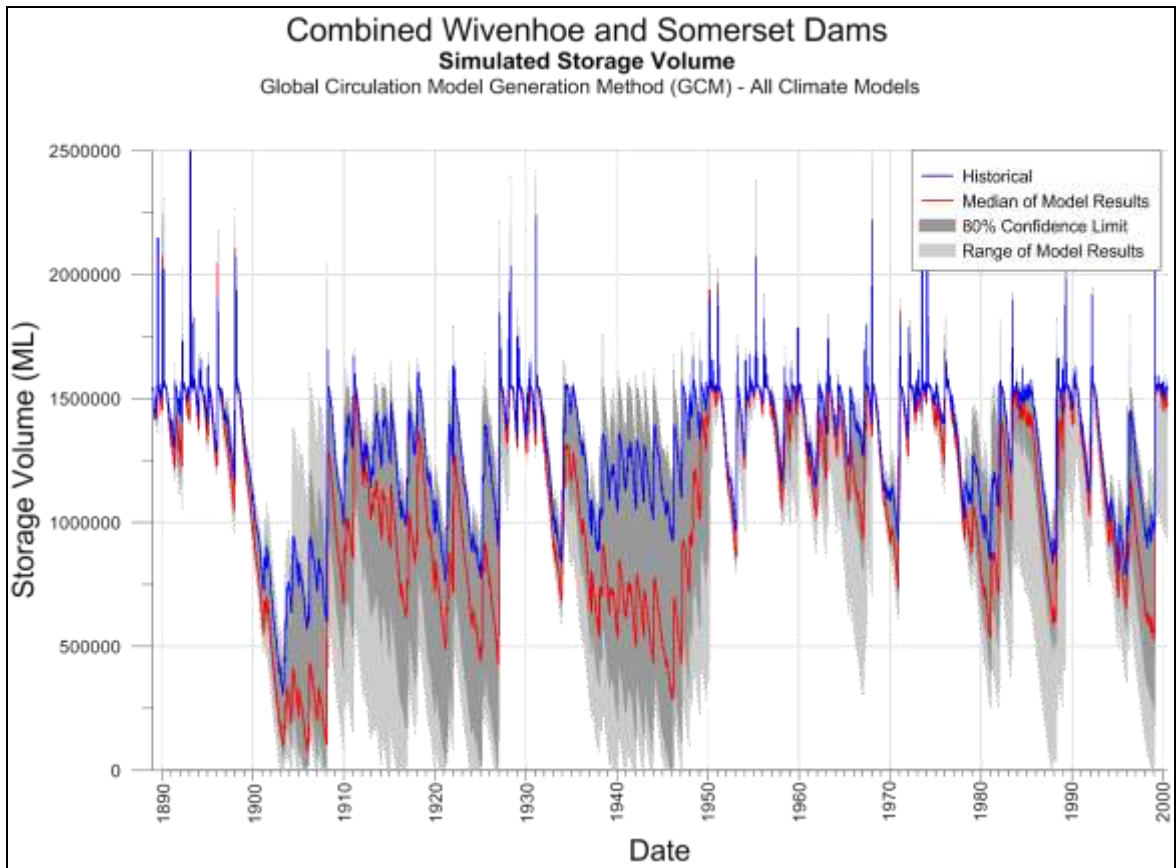


Figure G.3 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and Range of GCM Climate Model Results (for All Climate Models).

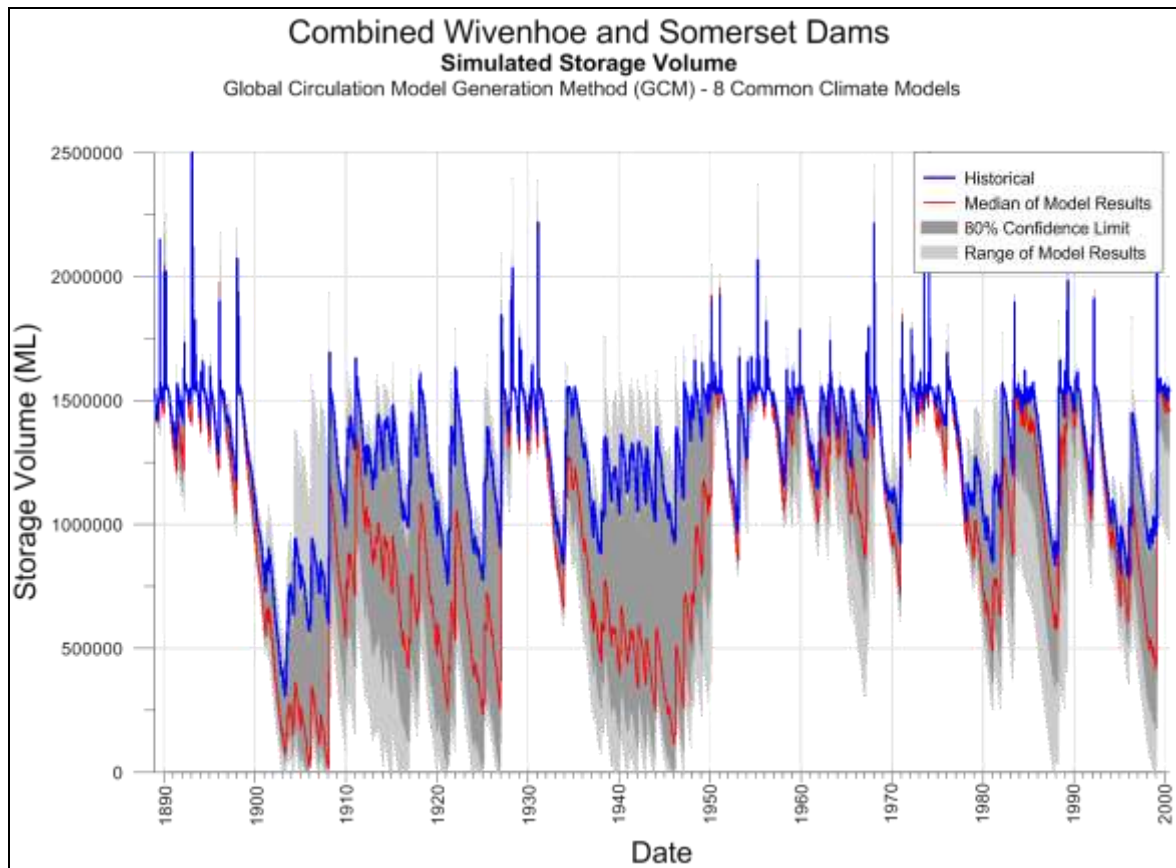


Figure G.4 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and Range of GCM Climate Model Results (for 8 Common Climate Models).

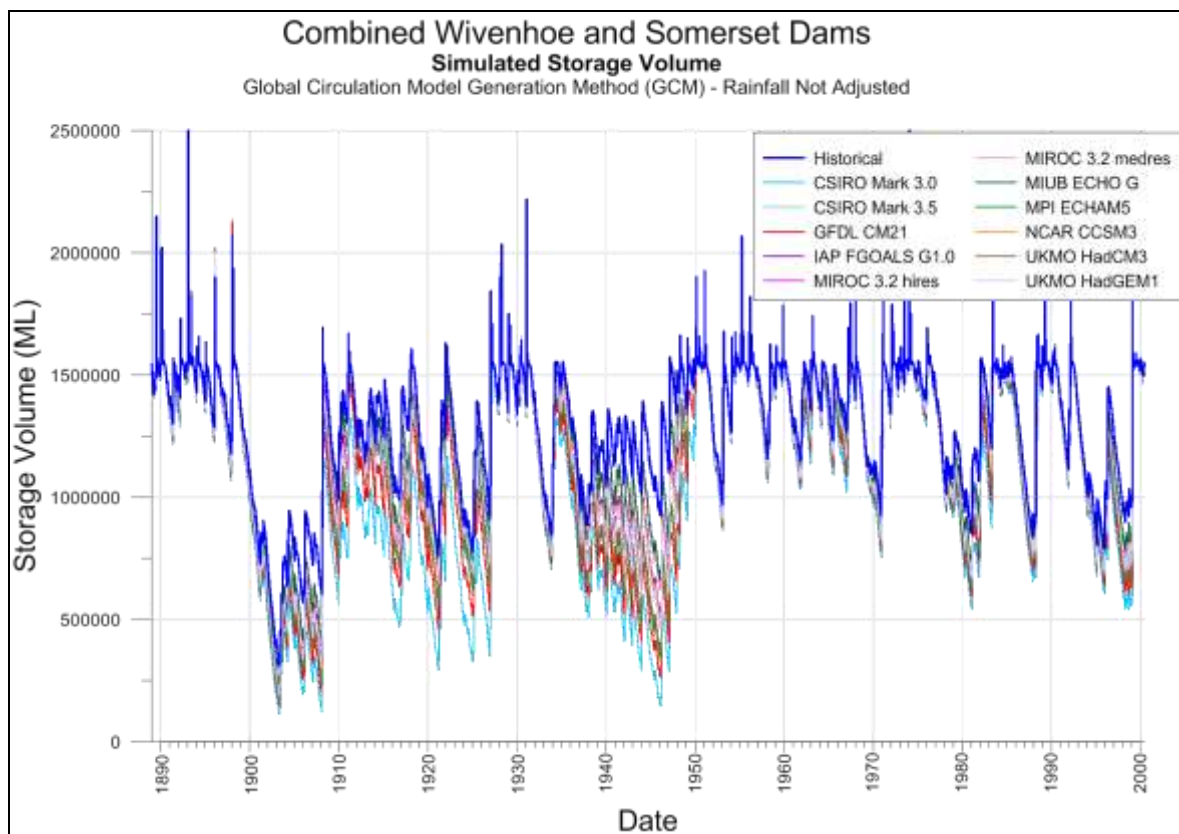


Figure G.5 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and GCM Climate Models (Rainfall Not Adjusted).

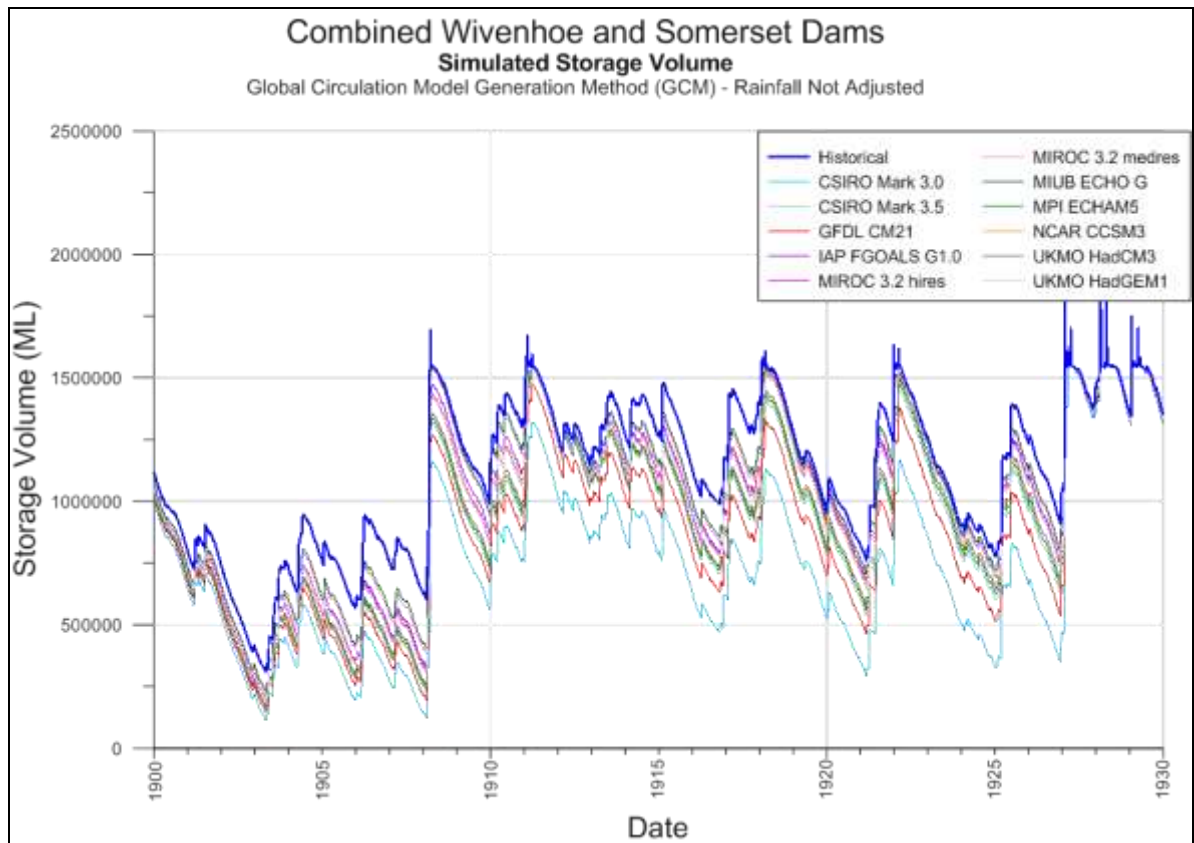


Figure G.6 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and GCM Climate Models (Rainfall Not Adjusted) (zoomed).

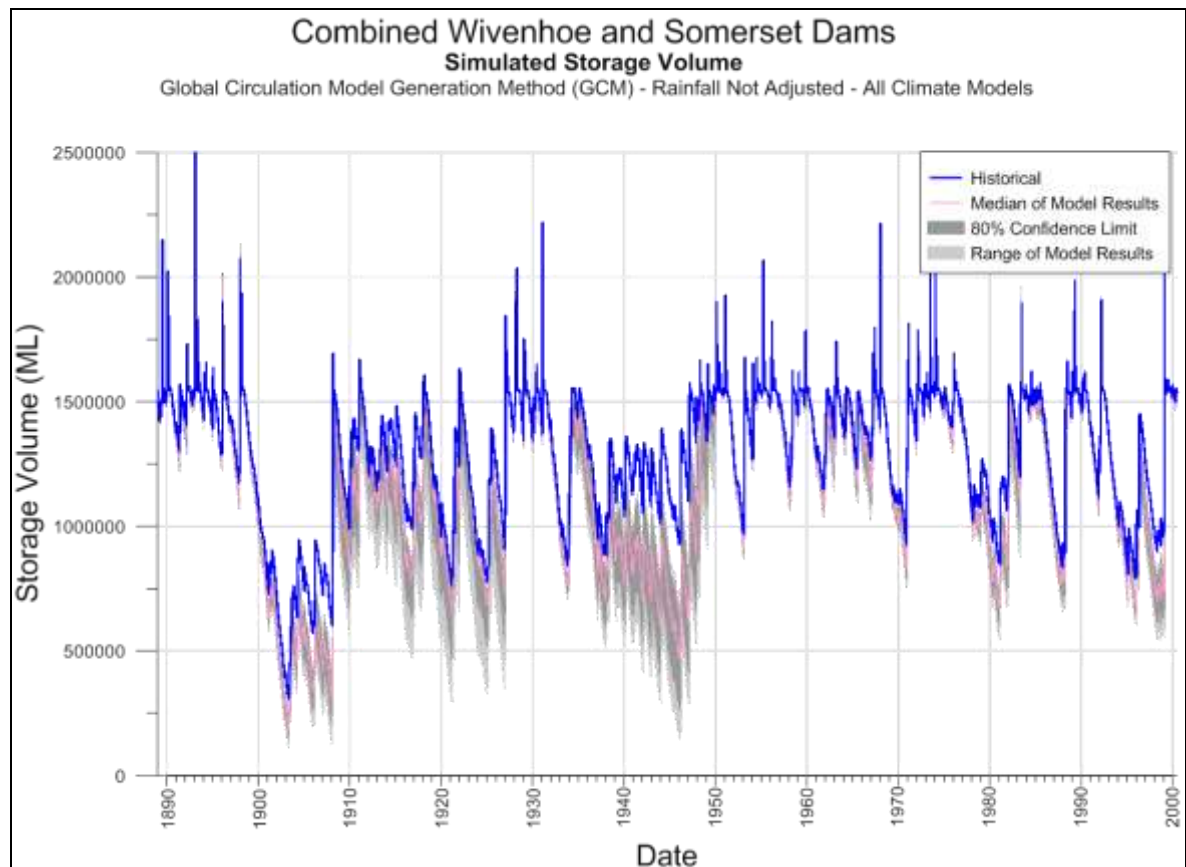


Figure G.7 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and Range of GCM Climate Model Results (Rainfall Not Adjusted) (for All Climate Models).

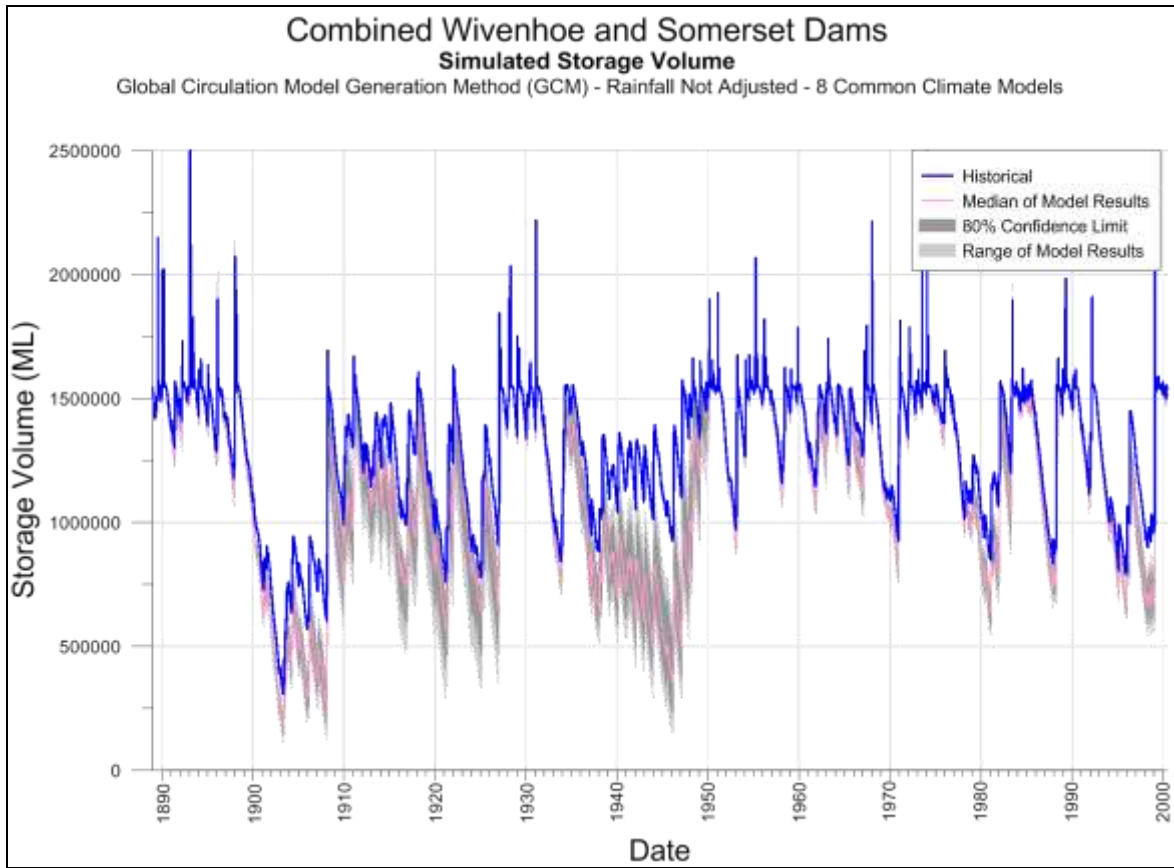


Figure G.8 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and Range of GCM Climate Model Results (Rainfall Not Adjusted) (for 8 Common Climate Models).

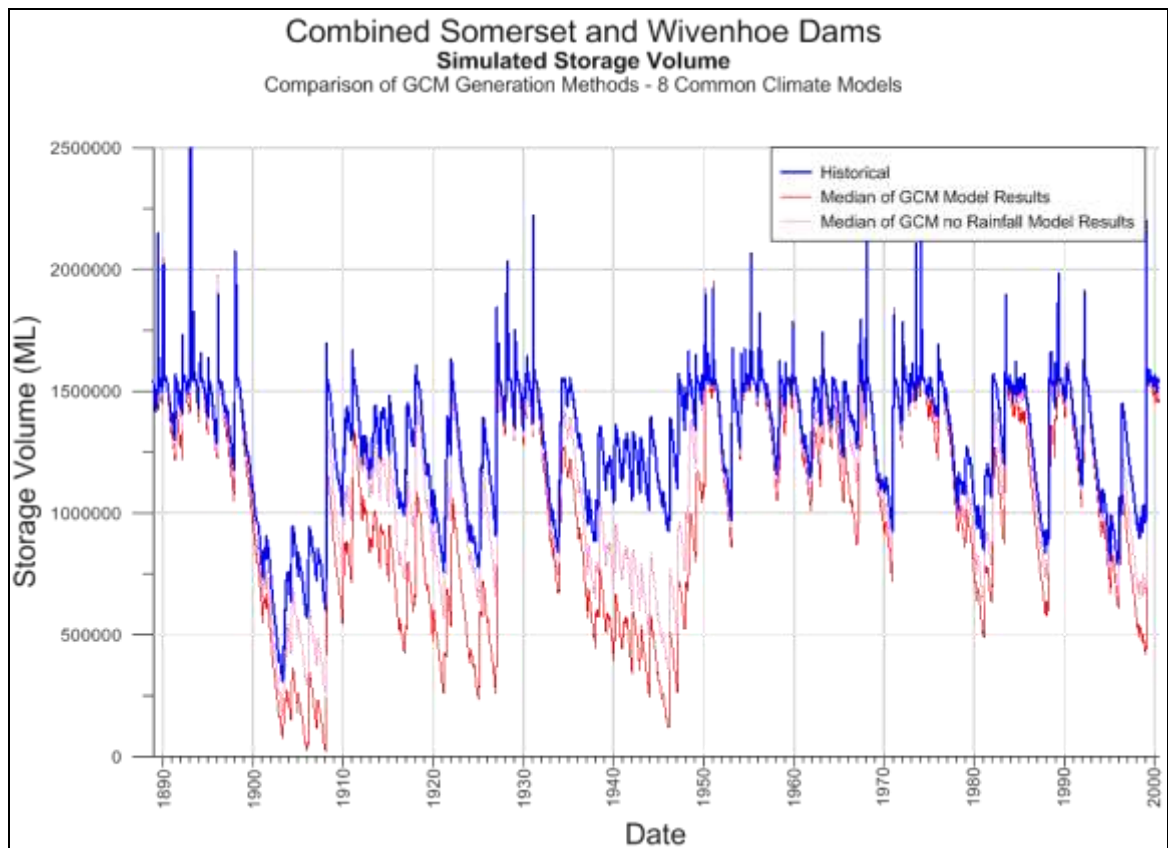


Figure G.9 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and Median GCM Climate Model Results (With and Without Rainfall Adjusted) (for 8 Common Climate Models).

G.2 Downscaled Generation Method

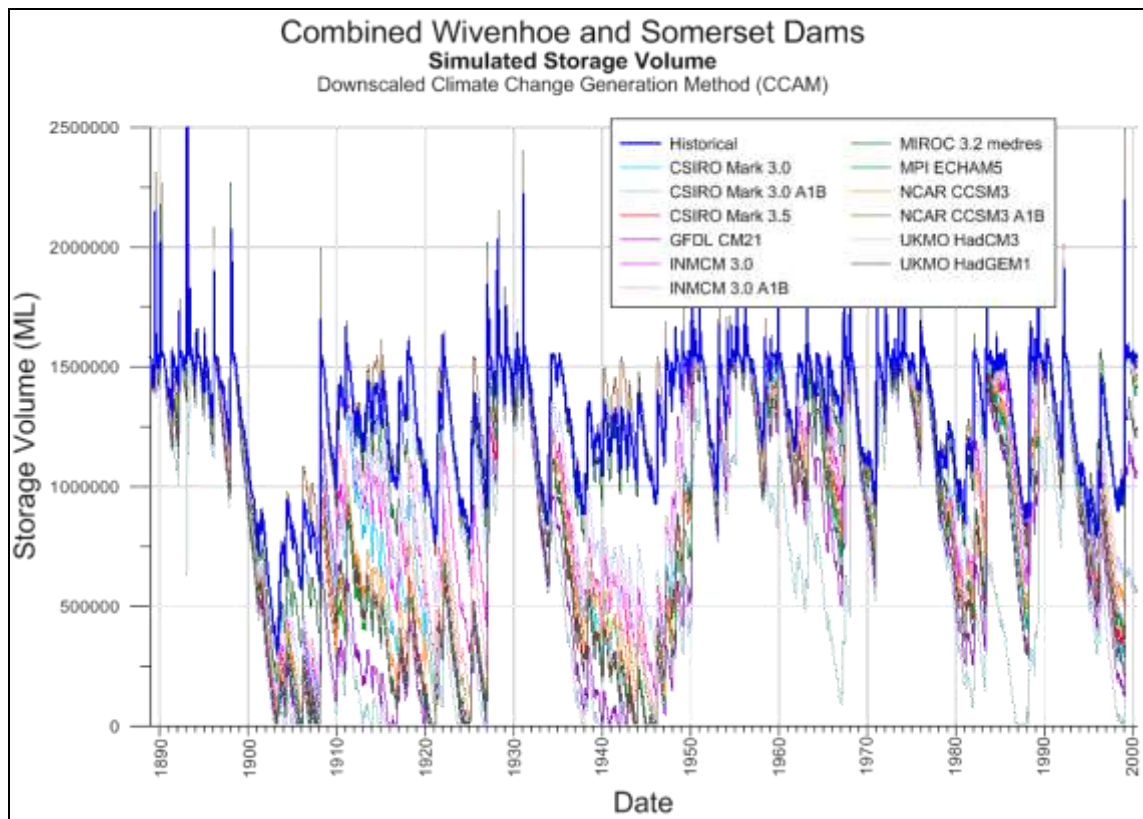


Figure G.10 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and CCAM Climate Models.

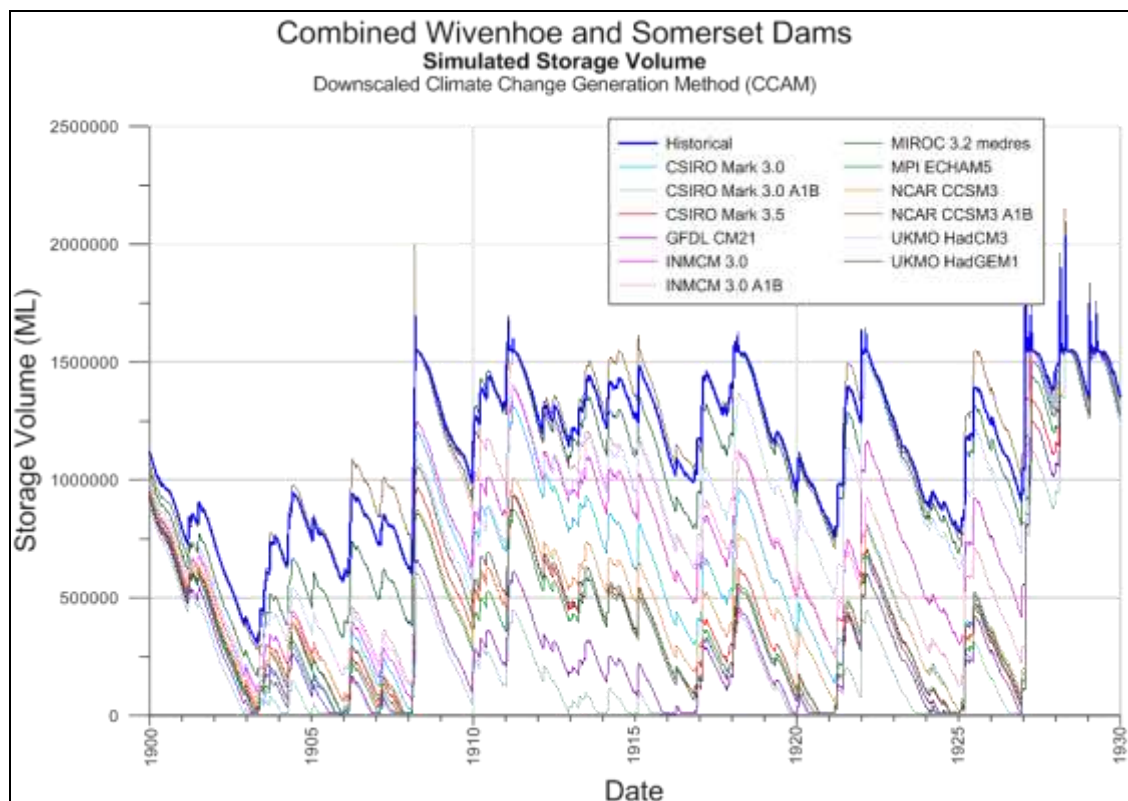


Figure G.11 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and CCAM Climate Models.

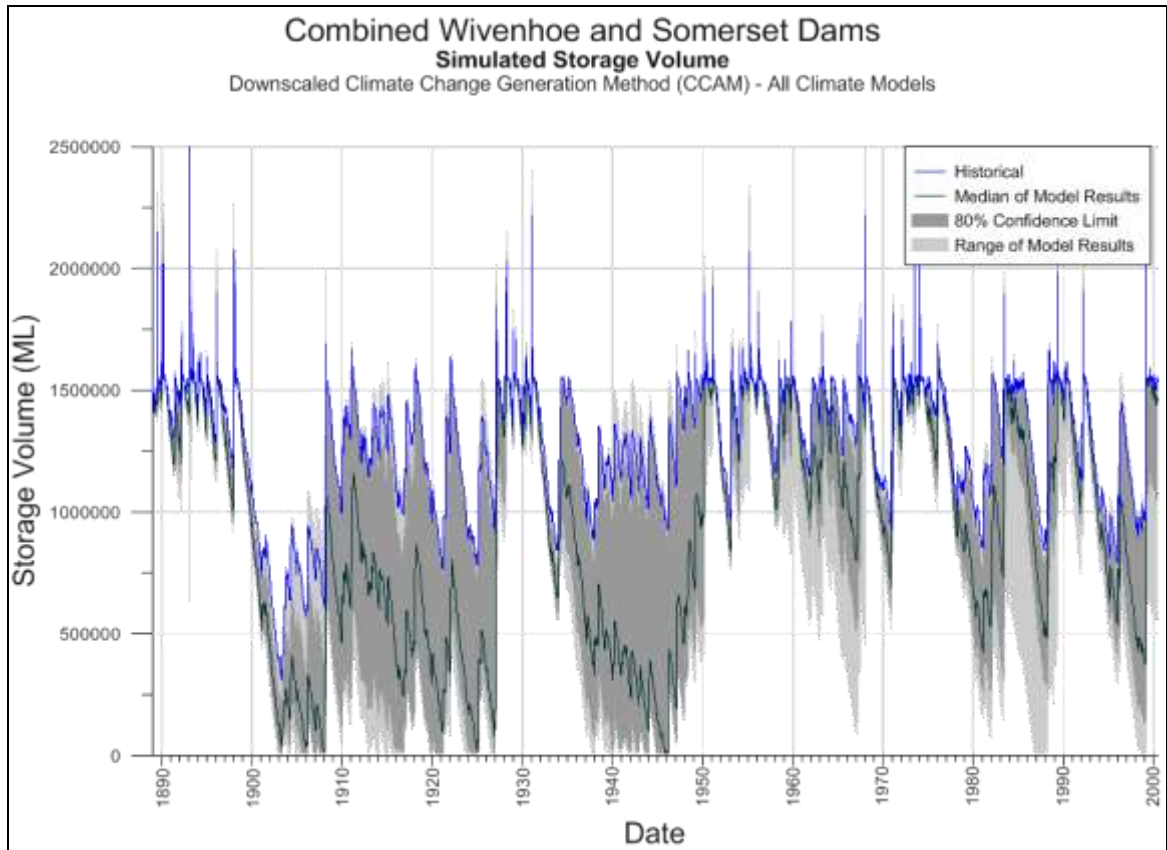


Figure G.12 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and Range of CCAM Climate Model Results (for All Climate Models).

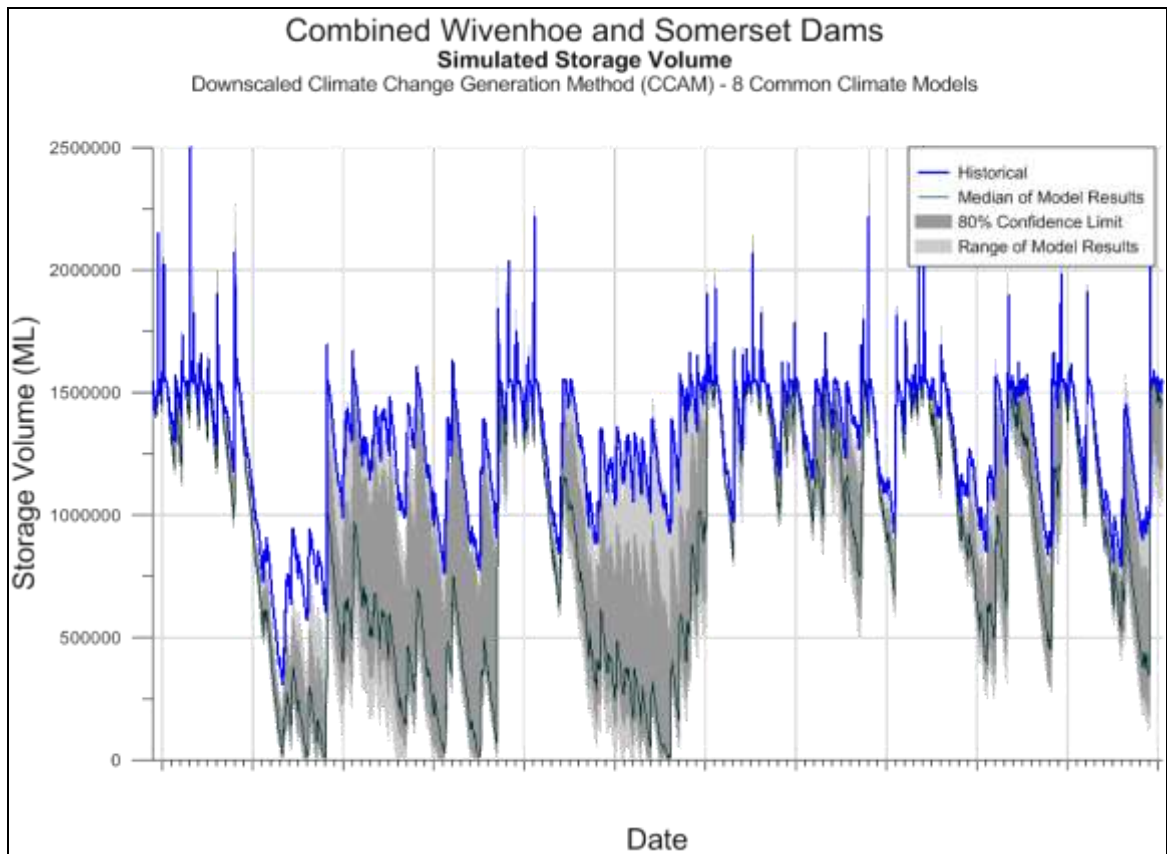


Figure G.13 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and Range of CCAM Climate Model Results (for 8 Common Climate Models).

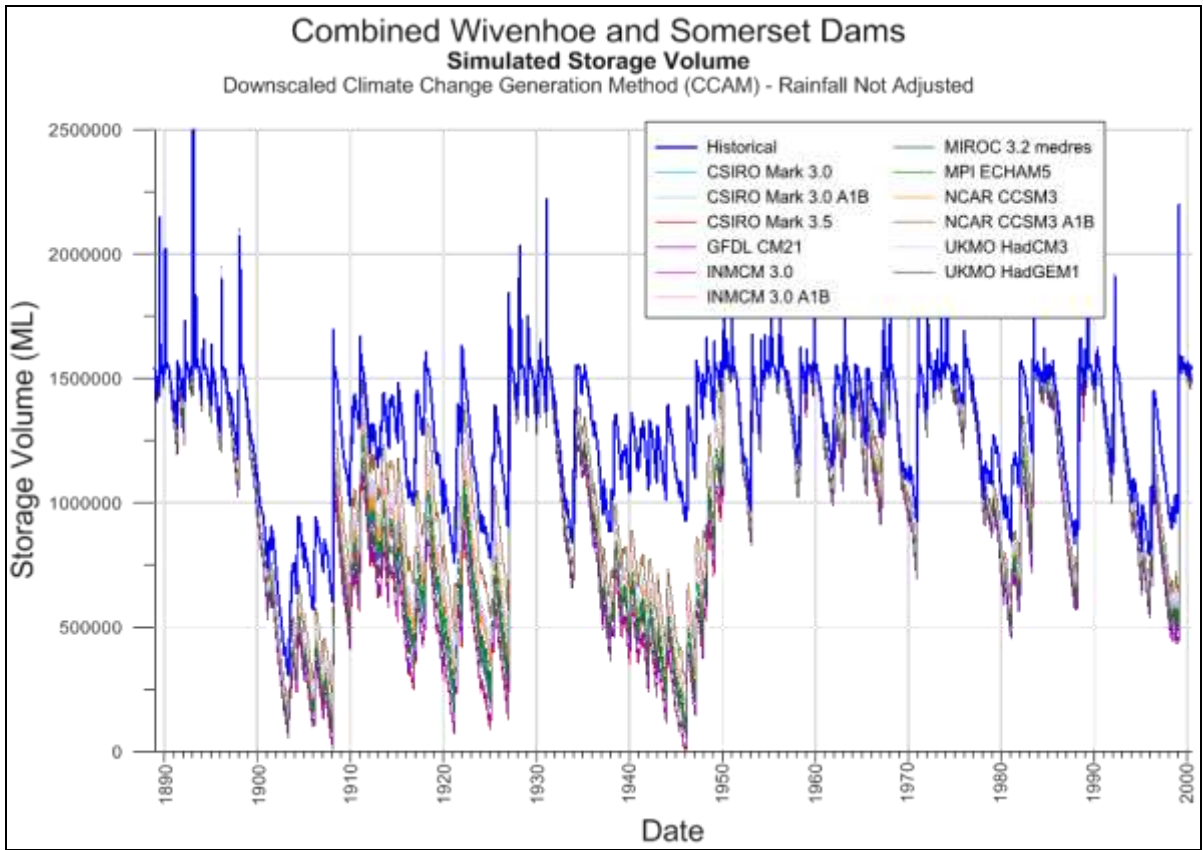


Figure G.14 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and CCAM Climate Models (Rainfall Not Adjusted).

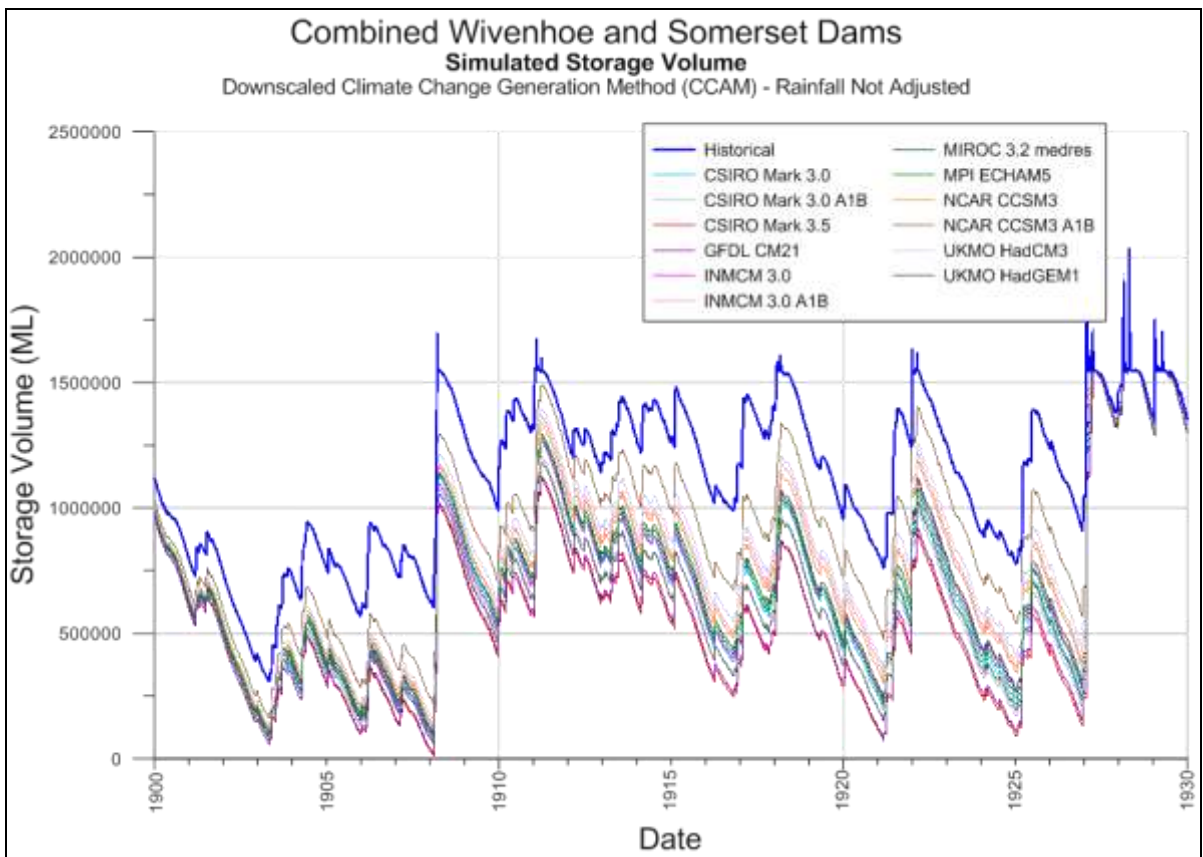


Figure G.15 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and CCAM Climate Models (Rainfall Not Adjusted) (zoomed).

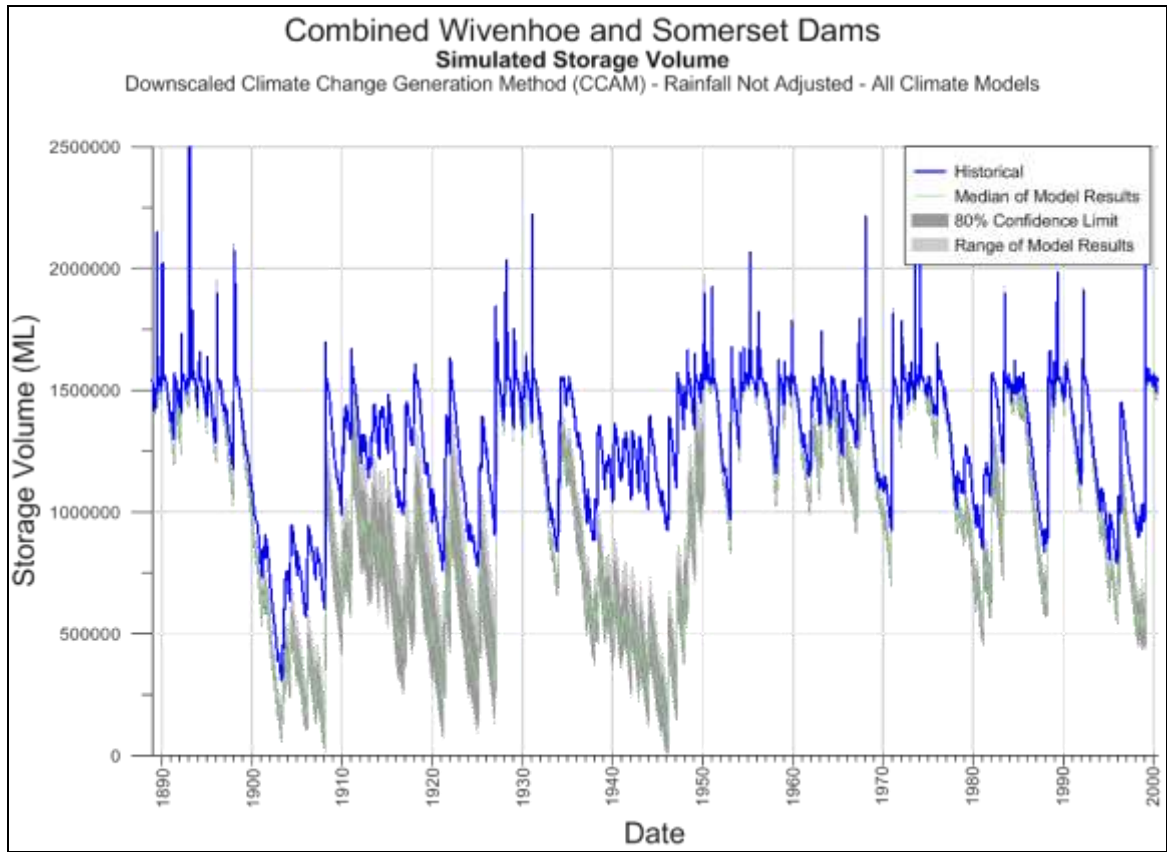


Figure G.16 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and Range of CCAM Climate Model Results (Rainfall Not Adjusted) (for All Climate Models).

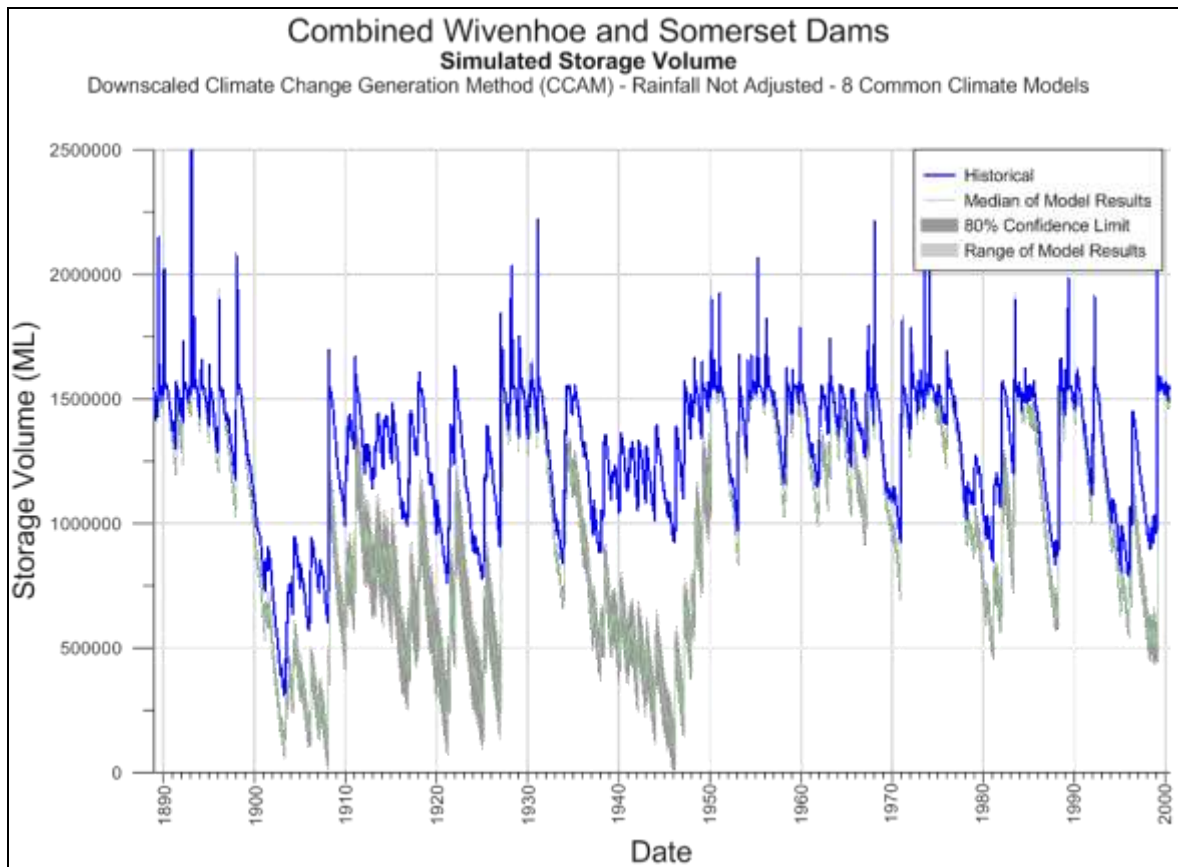


Figure G.17 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and Range of CCAM Climate Model Results (Rainfall Not Adjusted) (for 8 Common Climate Models).

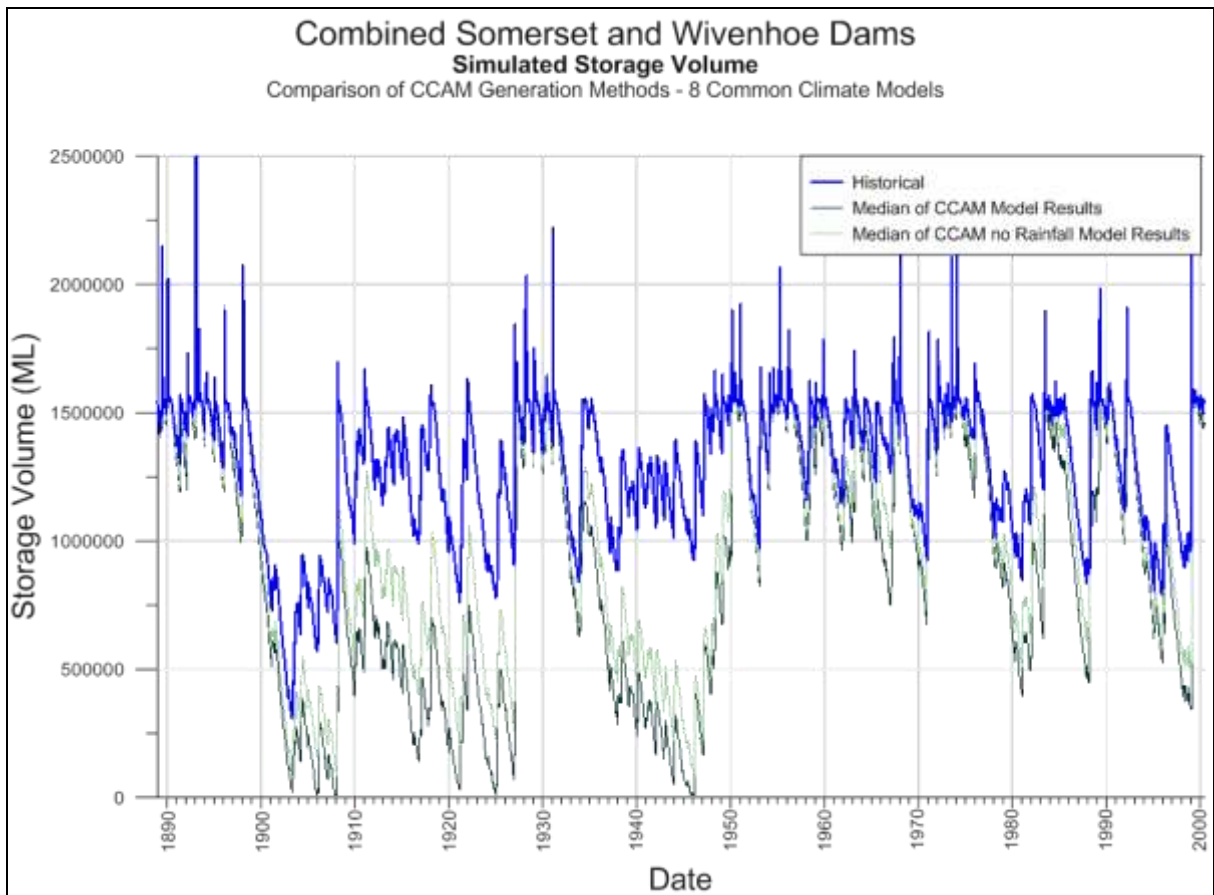


Figure G.18 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and Median CCAM Climate Model Results (With and Without Rainfall Adjusted) (for 8 Common Climate Models).

G.3 Comparison of Generation Methods

G.3.1 GCM and CCAM

Table 7.23 Description of Relevant Generation Methods.

Generation Method	Gridsize	Description
GCM	Ranging from 100 to 400km	Global circulation models developed by various research institutes around the world
CCAM	~20km	Original dynamically downscaled models using the Conformal-Cubic Atmospheric Model (CCAM) – downscaled to 20km

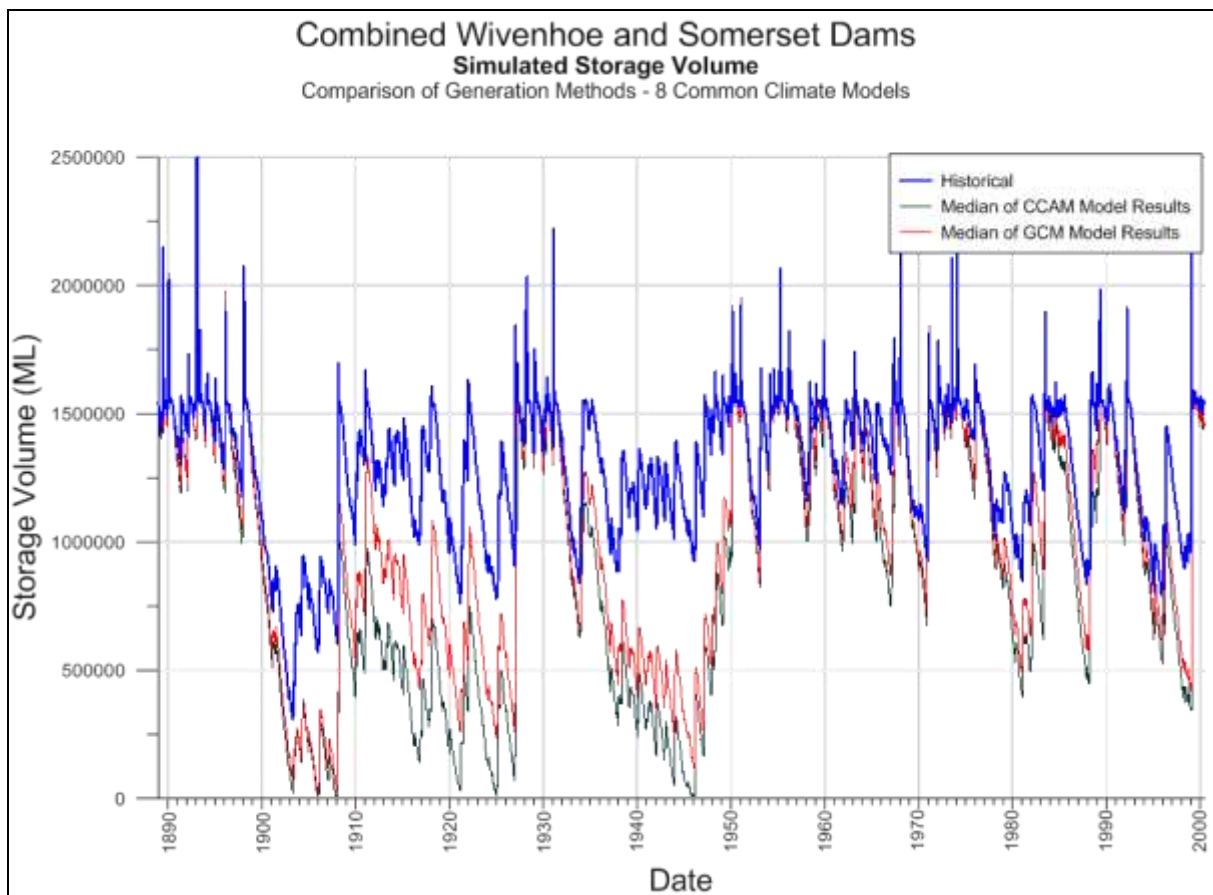


Figure G.19 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and Median GCM and CCAM Climate Model Results (for 8 Common Climate Models).

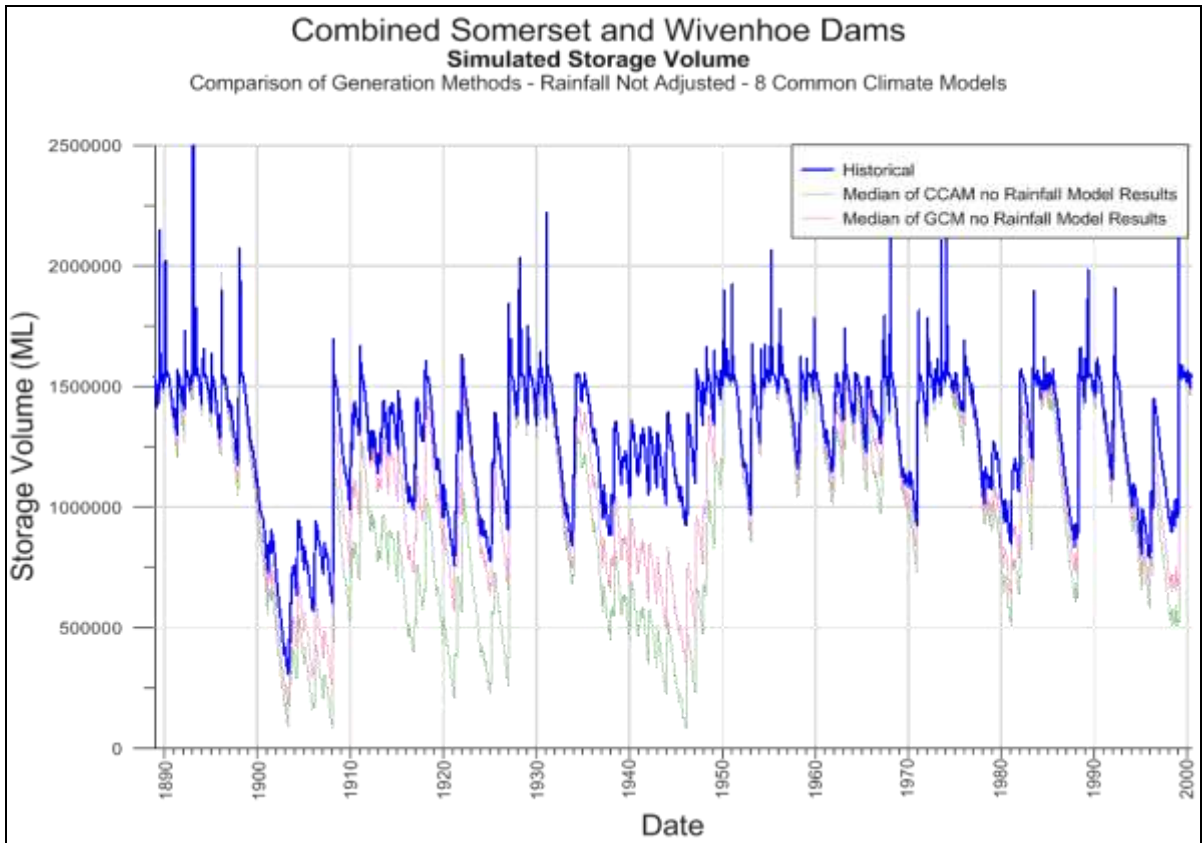


Figure G.20 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and Median GCM and CCAM Climate Model Results (Rainfall Not Adjusted) (for 8 Common Climate Models).

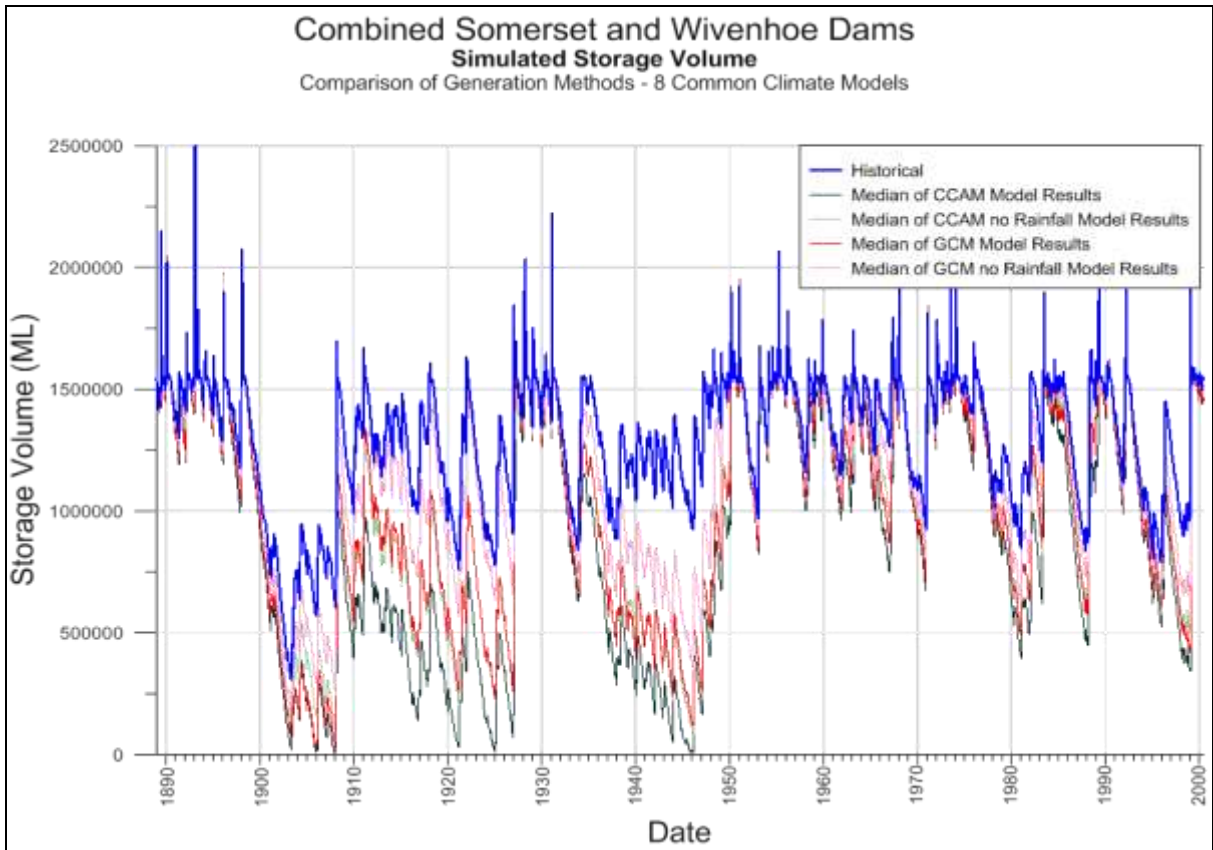


Figure G.21 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and Median GCM and CCAM Climate Model Results (With and Without Rainfall Adjusted) (for 8 Common Climate Models).

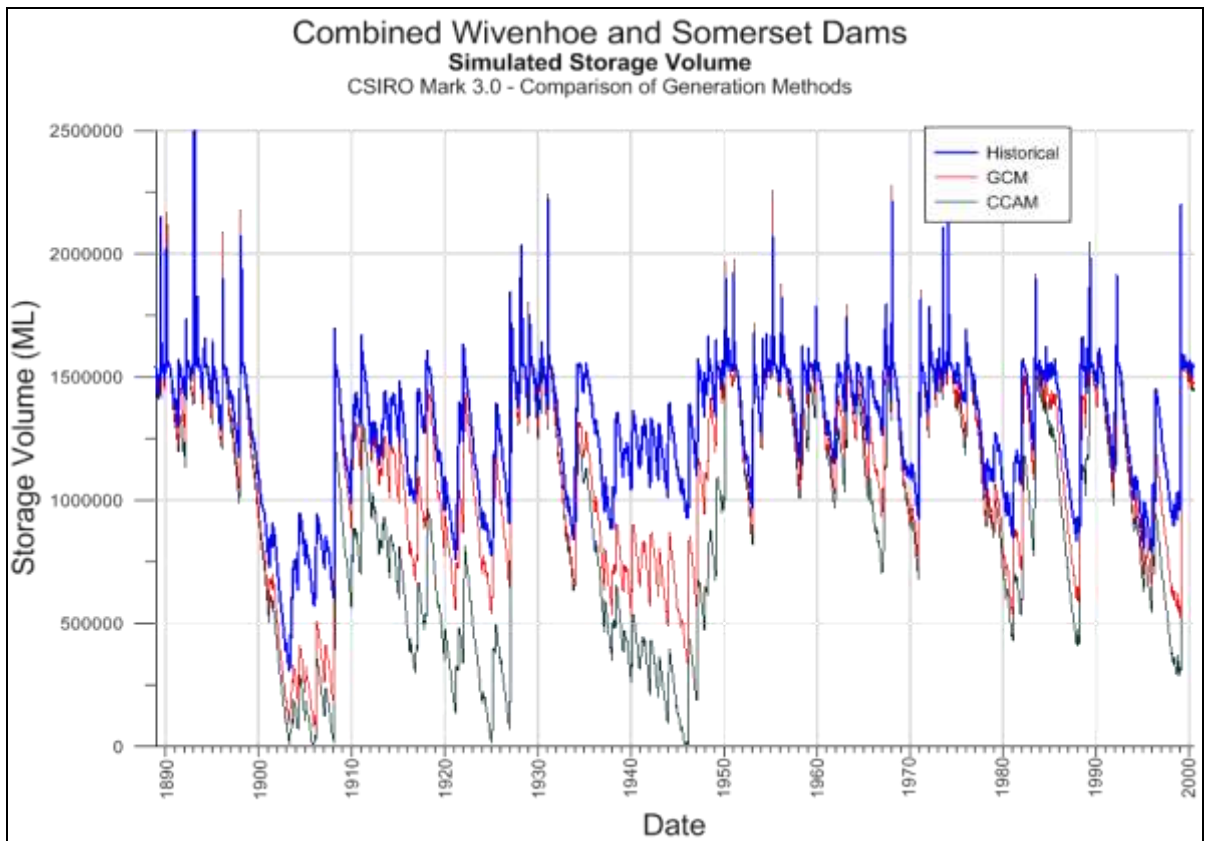


Figure G.22 Combined Wivenhoe and Somerset Dam Storage Volume – Historical, GCM and CCAM – CSIRO Mark 3.0.

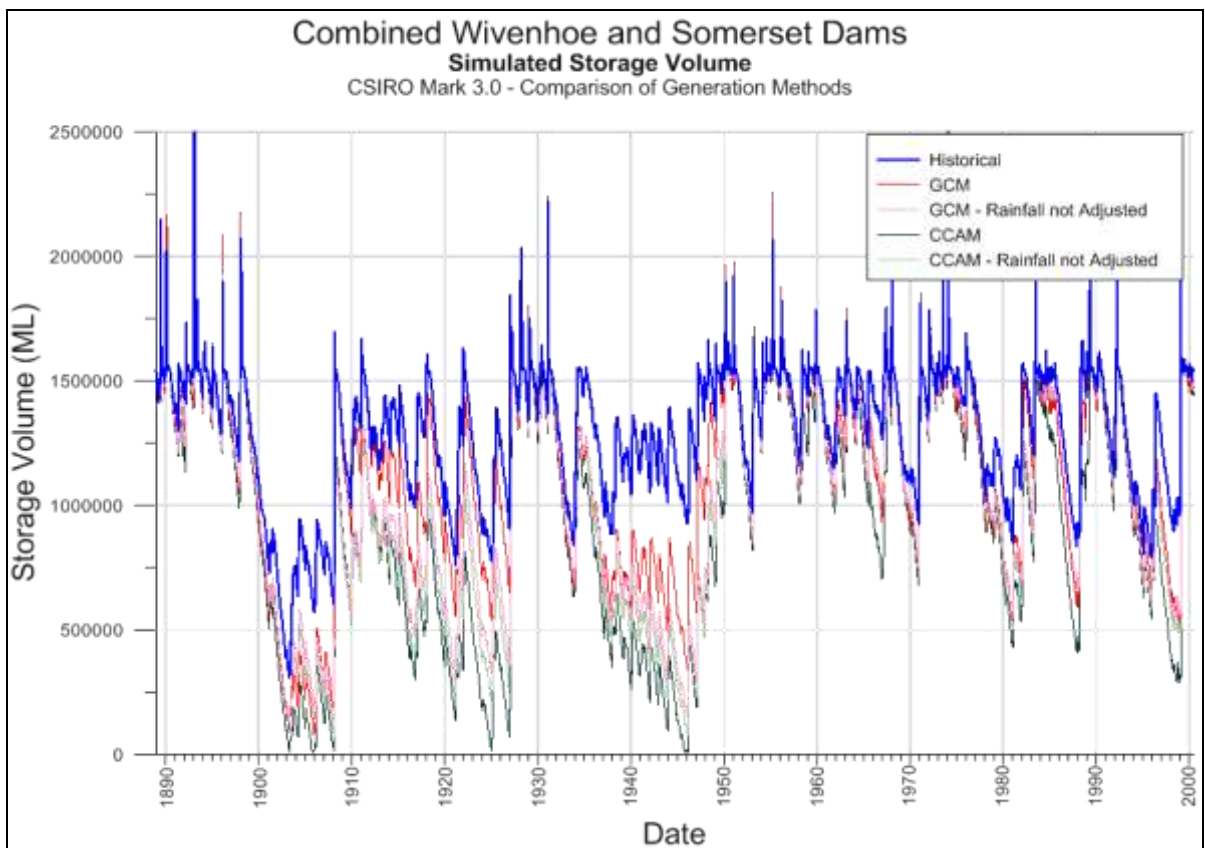


Figure G.23 Combined Wivenhoe and Somerset Dam Storage Volume – Historical, GCM and CCAM – CSIRO Mark 3.0 (With and Without Rainfall Adjusted).

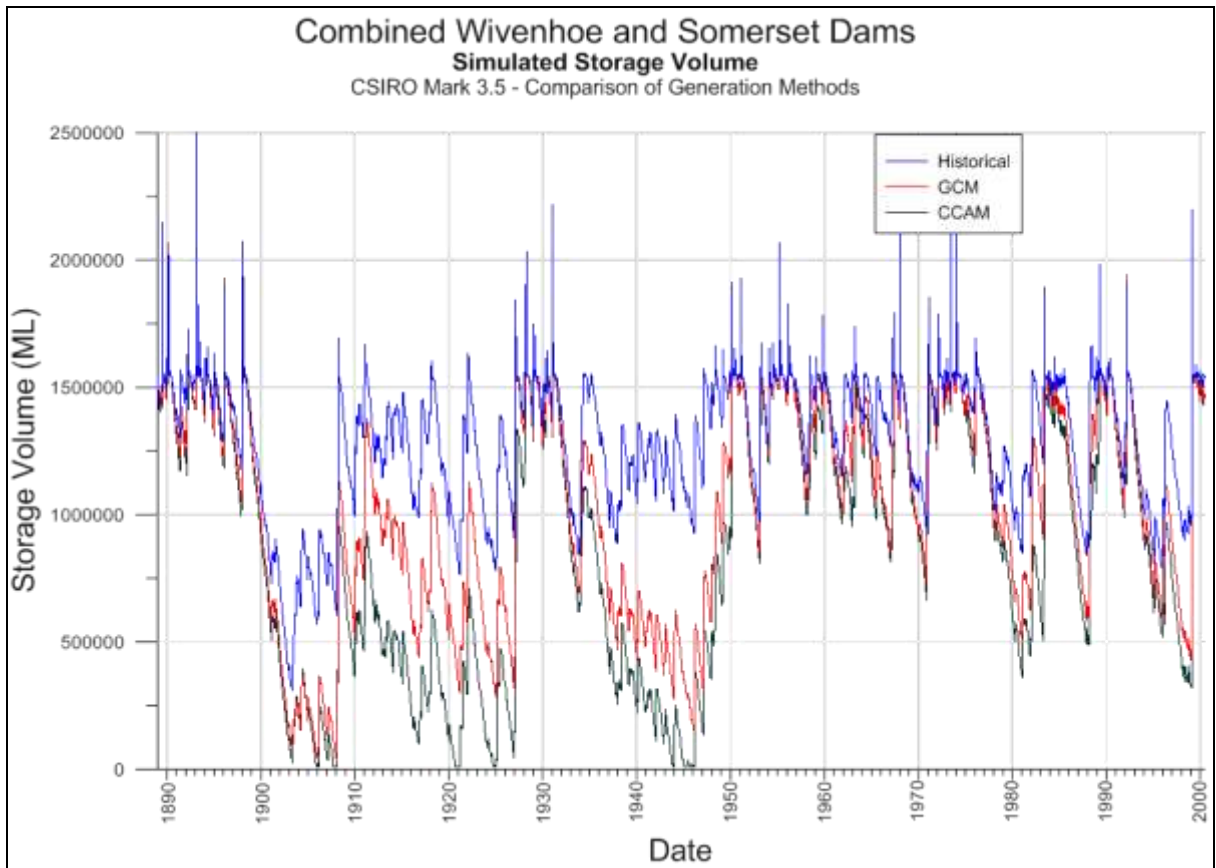


Figure G.24 Combined Wivenhoe and Somerset Dam Storage Volume – Historical, GCM and CCAM – CSIRO Mark 3.5.

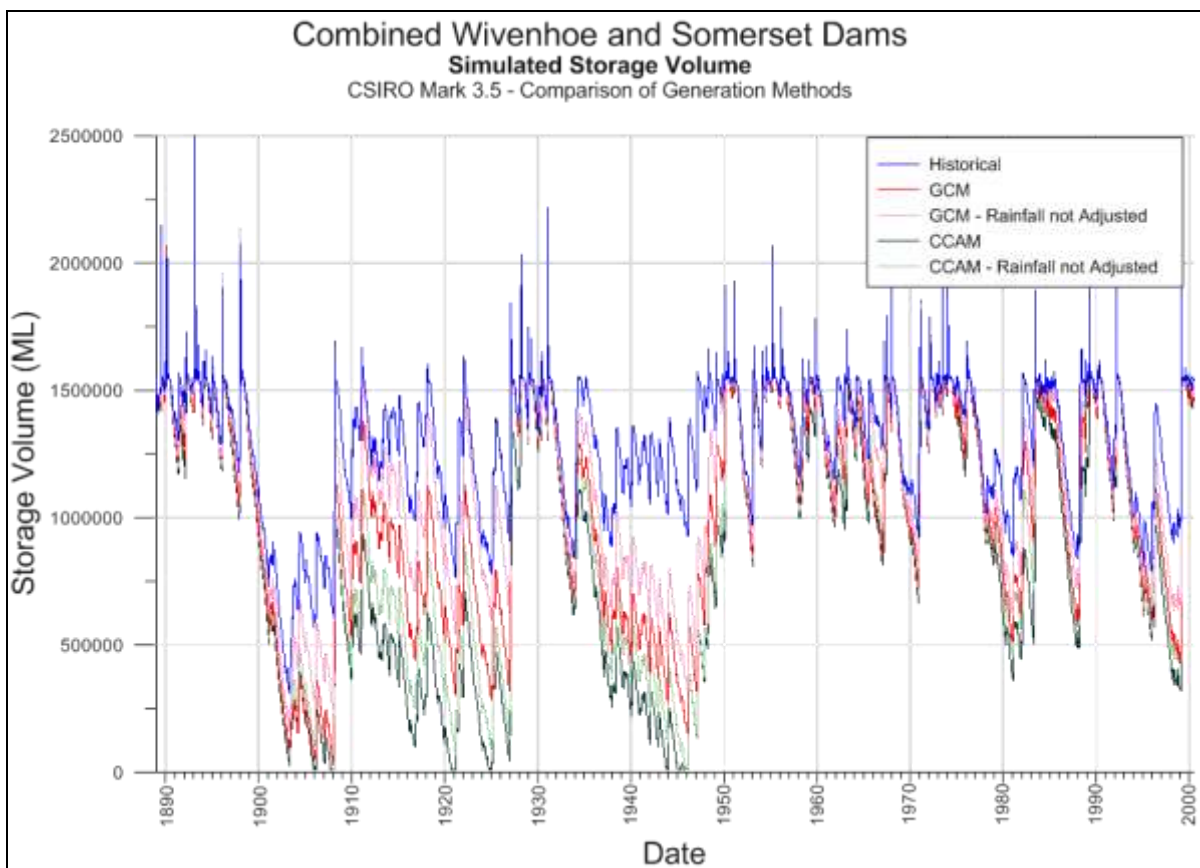


Figure G.25 Combined Wivenhoe and Somerset Dam Storage Volume – Historical, GCM and CCAM – CSIRO Mark 3.5 (With and Without Rainfall Adjusted).

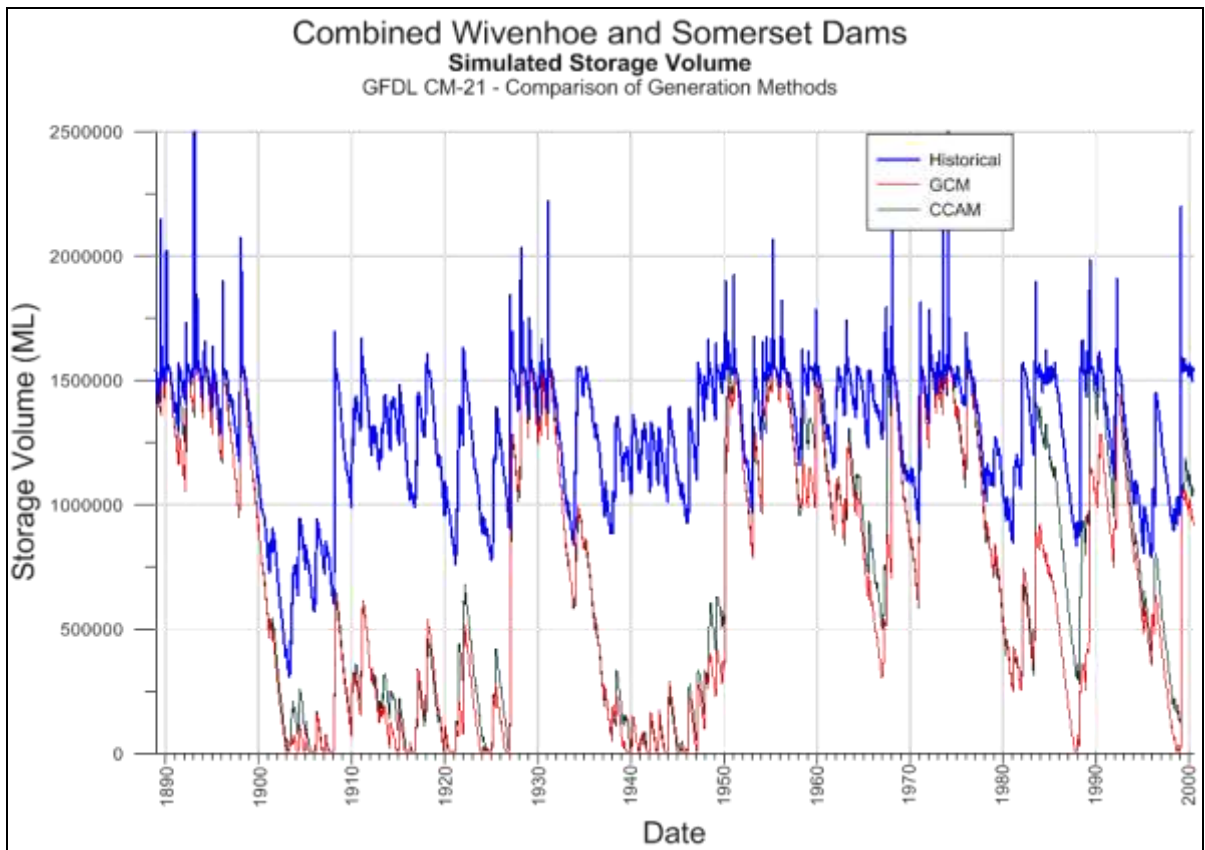


Figure G.26 Combined Wivenhoe and Somerset Dam Storage Volume – Historical, GCM and CCAM – GFDL CM21.

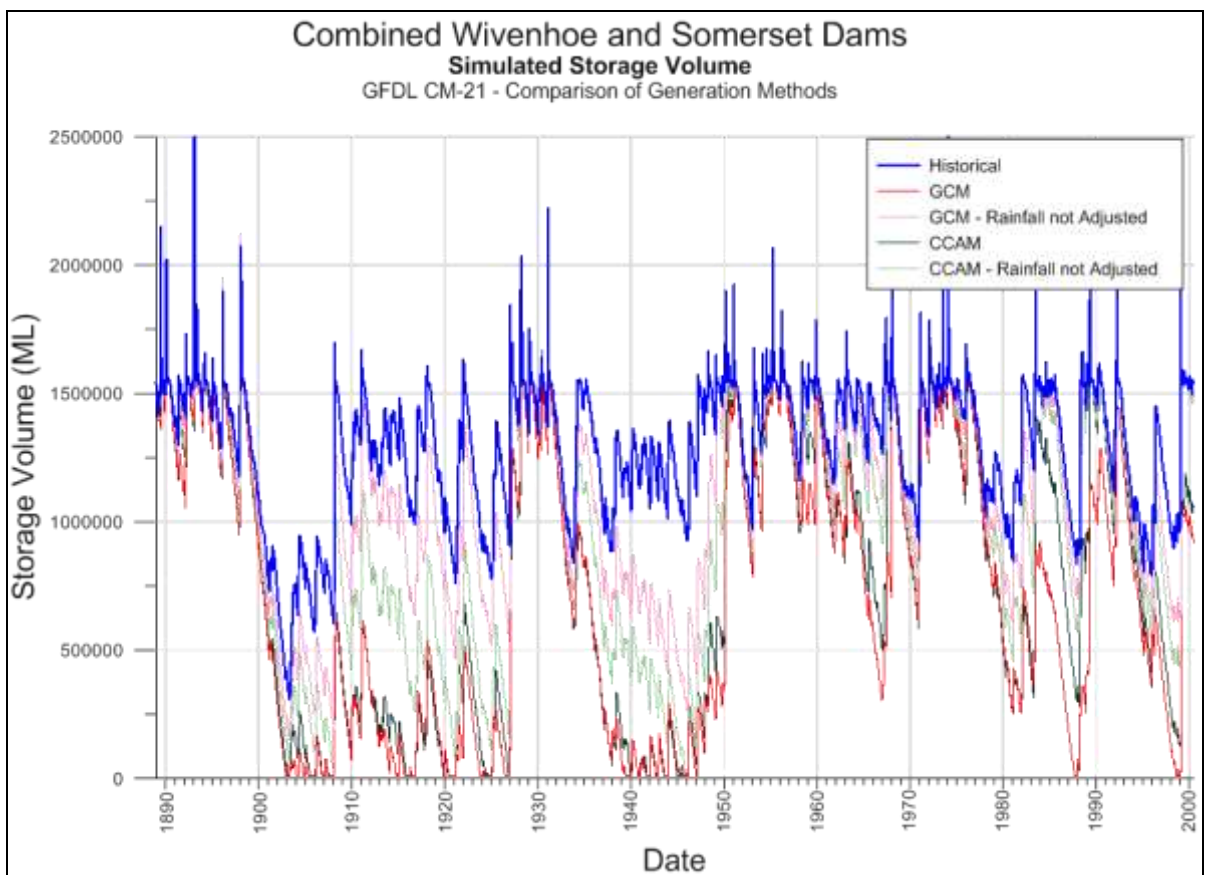


Figure G.27 Combined Wivenhoe and Somerset Dam Storage Volume – Historical, GCM and CCAM – GFDL CM21 (With and Without Rainfall Adjusted).

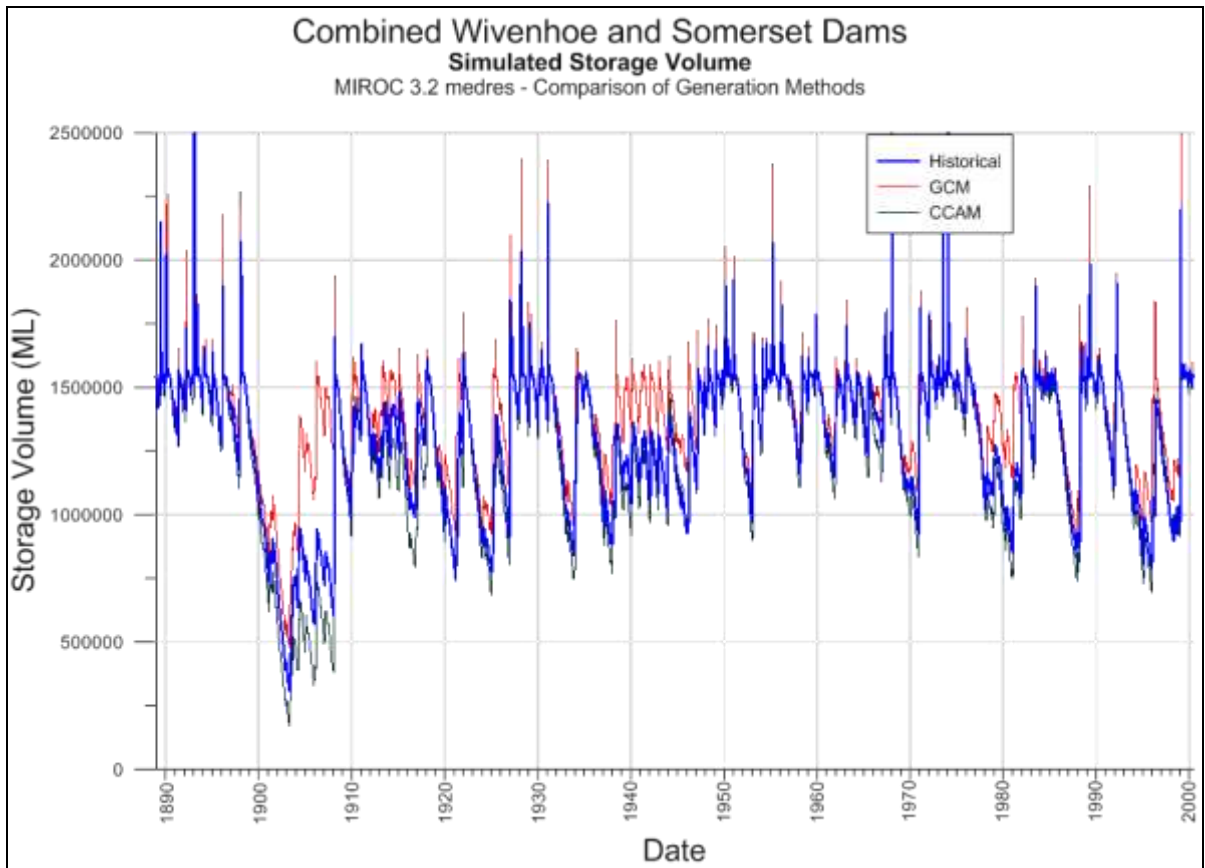


Figure G.28 Combined Wivenhoe and Somerset Dam Storage Volume – Historical, GCM and CCAM – MIROC 3.2 medres.

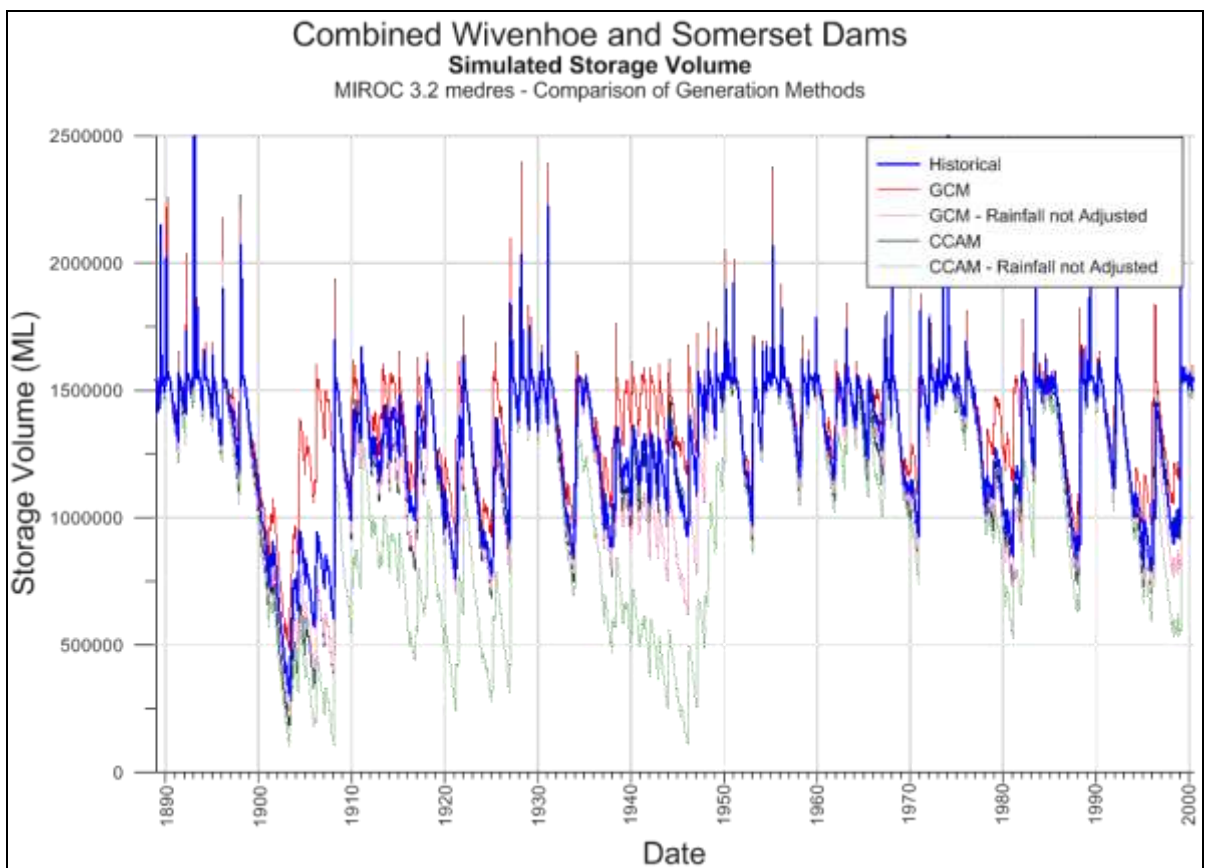


Figure G.29 Combined Wivenhoe and Somerset Dam Storage Volume – Historical, GCM and CCAM – MIROC 3.2 medres (With and Without Rainfall Adjusted).

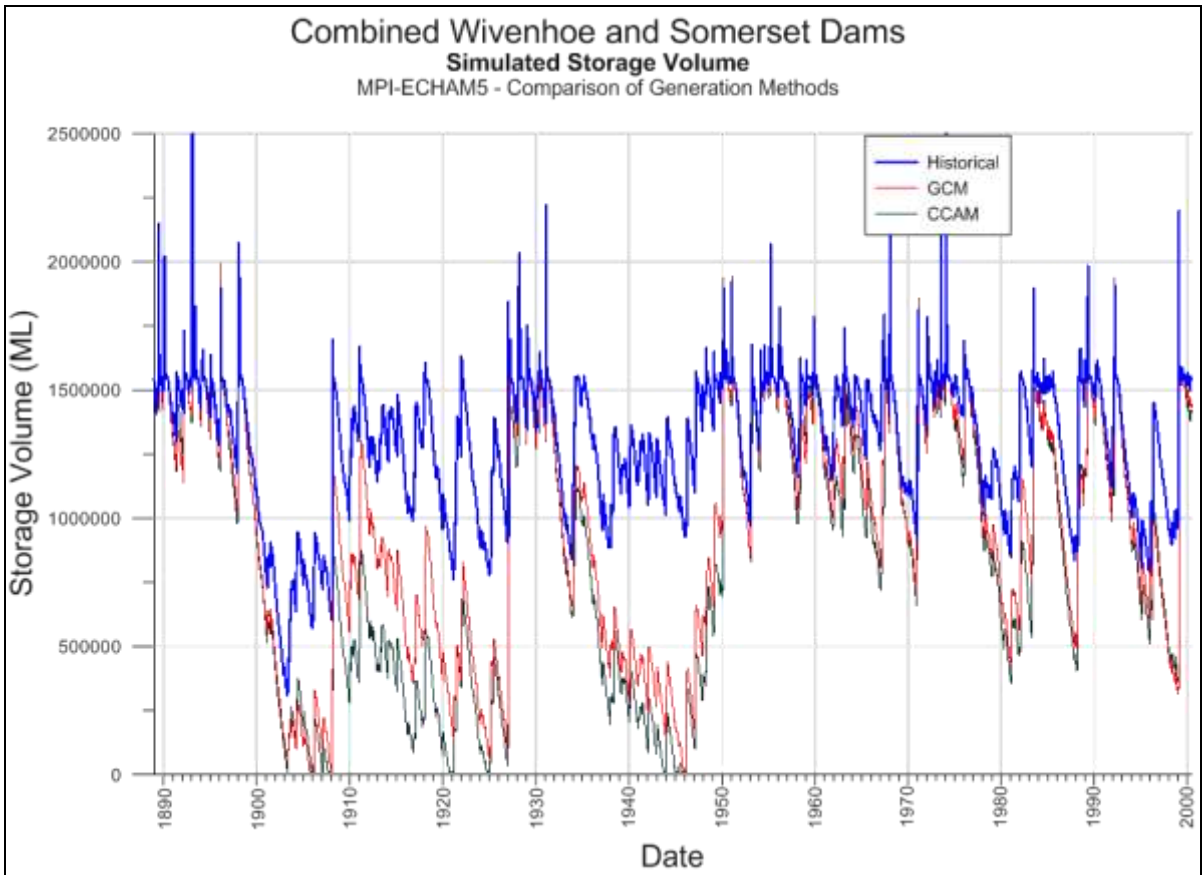


Figure G.30 Combined Wivenhoe and Somerset Dam Storage Volume – Historical, GCM and CCAM – MPI ECHAM5.

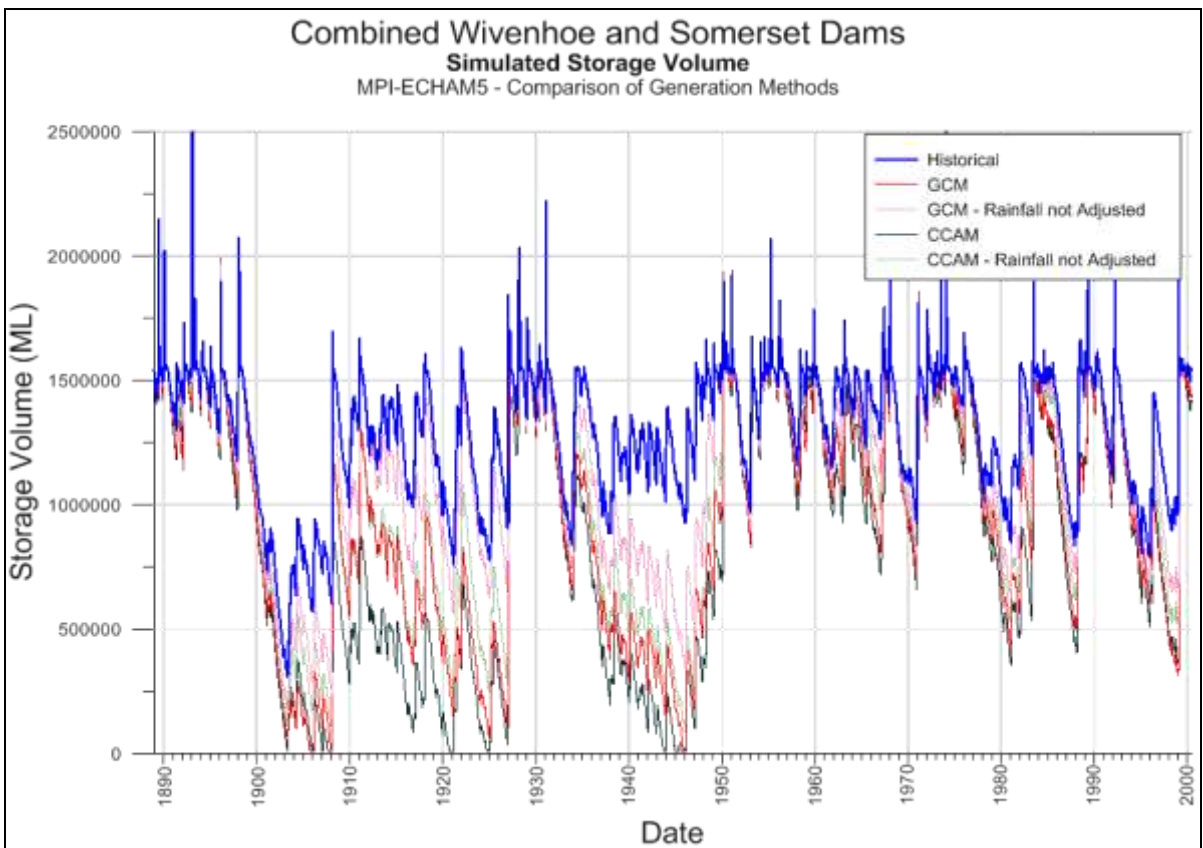


Figure G.31 Combined Wivenhoe and Somerset Dam Storage Volume – Historical, GCM and CCAM – MPI ECHAM5 (With and Without Rainfall Adjusted).

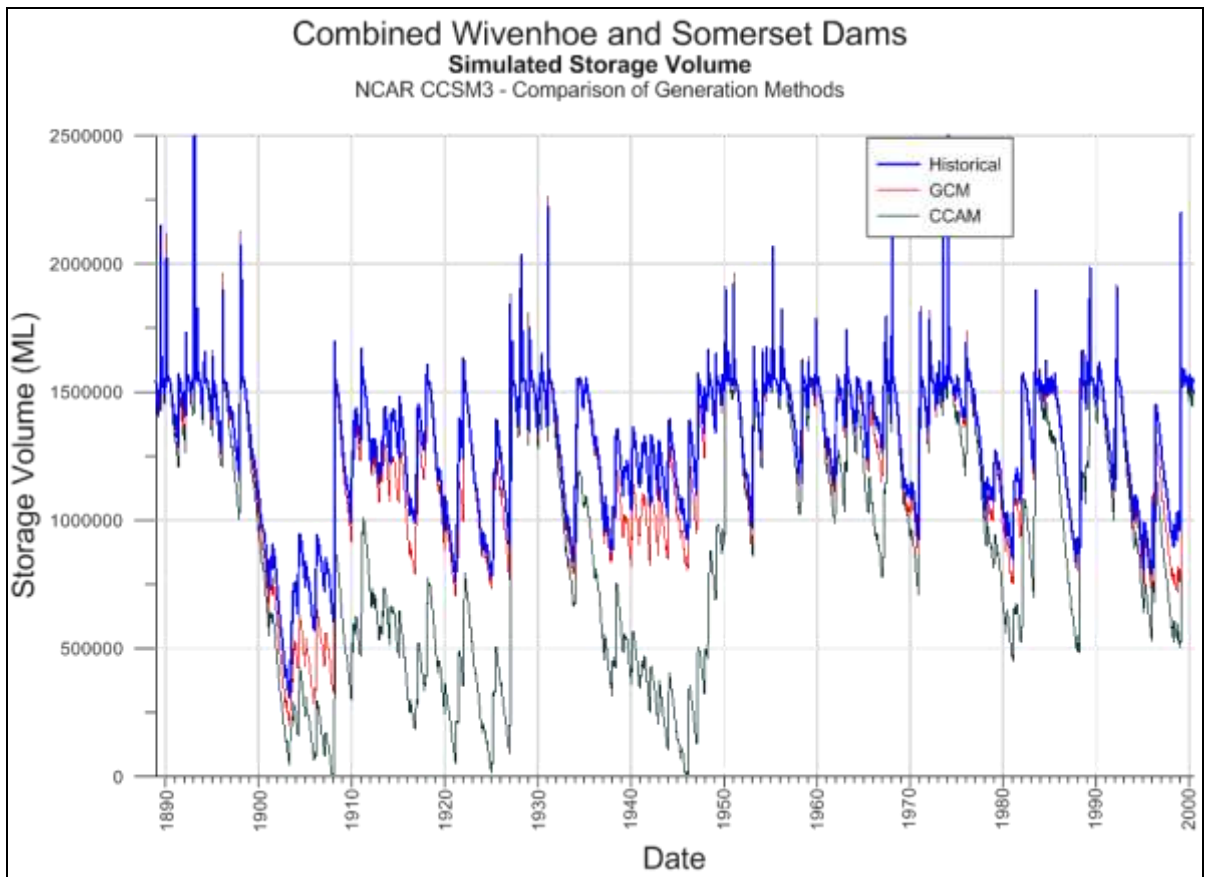


Figure G.32 Combined Wivenhoe and Somerset Dam Storage Volume – Historical, GCM and CCAM – NCAR CCSM3.

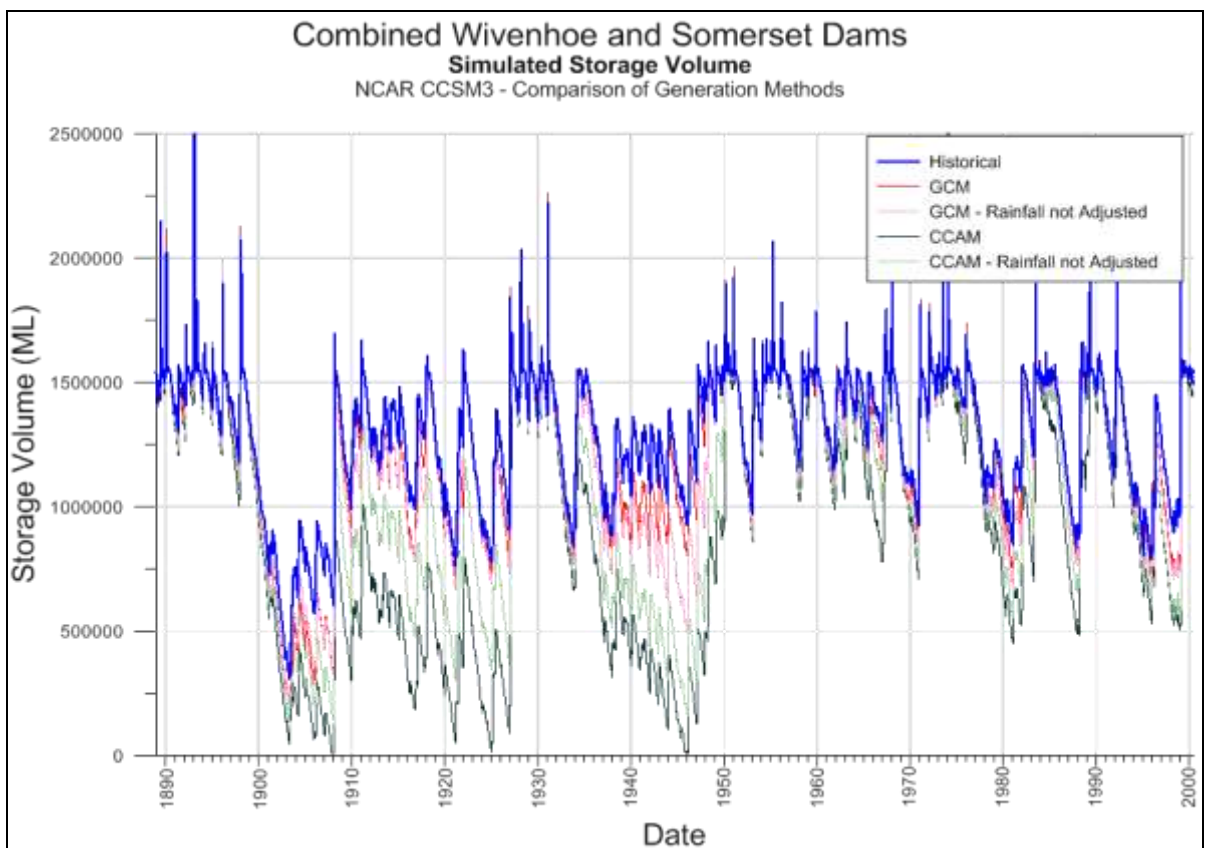


Figure G.33 Combined Wivenhoe and Somerset Dam Storage Volume – Historical, GCM and CCAM – NCAR CCSM3 (With and Without Rainfall Adjusted).

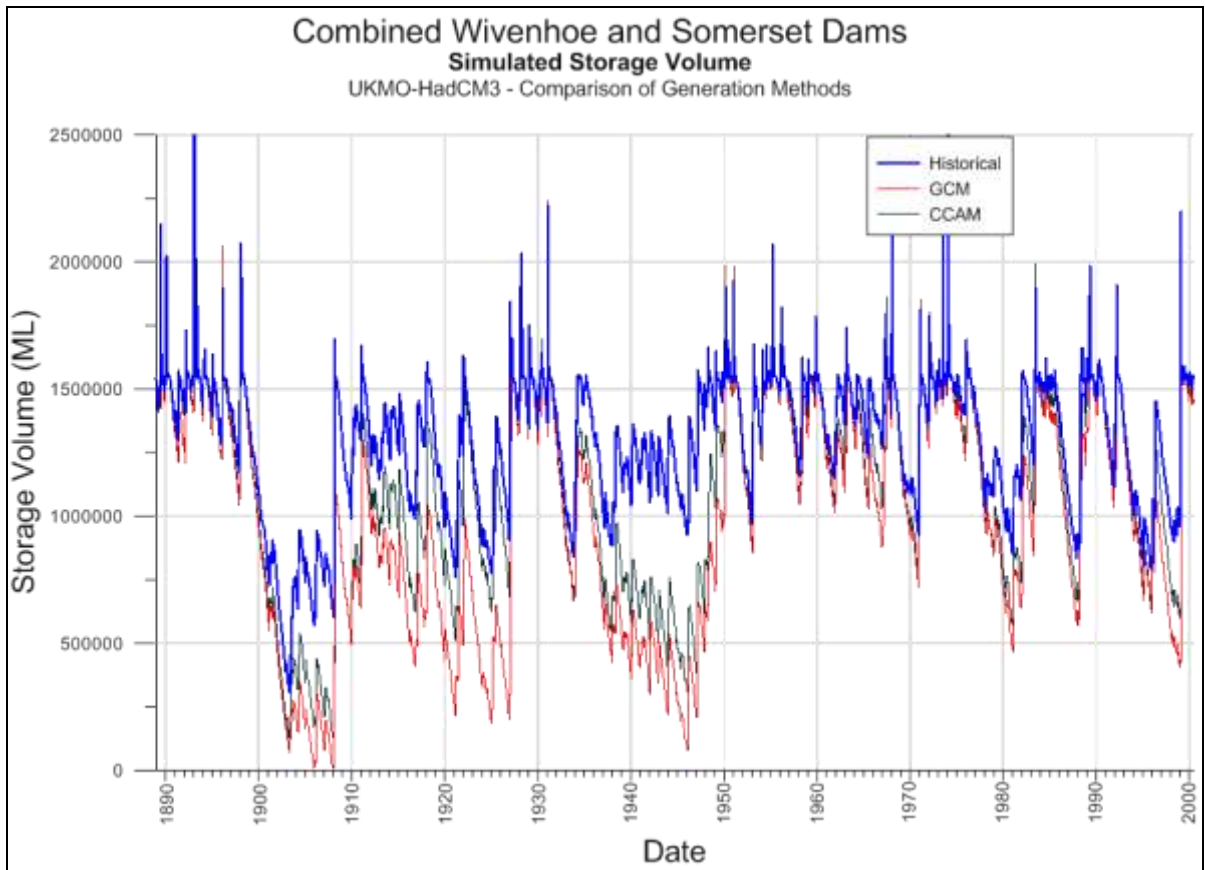


Figure G.34 Combined Wivenhoe and Somerset Dam Storage Volume – Historical, GCM and CCAM – UKMO HadCM3.

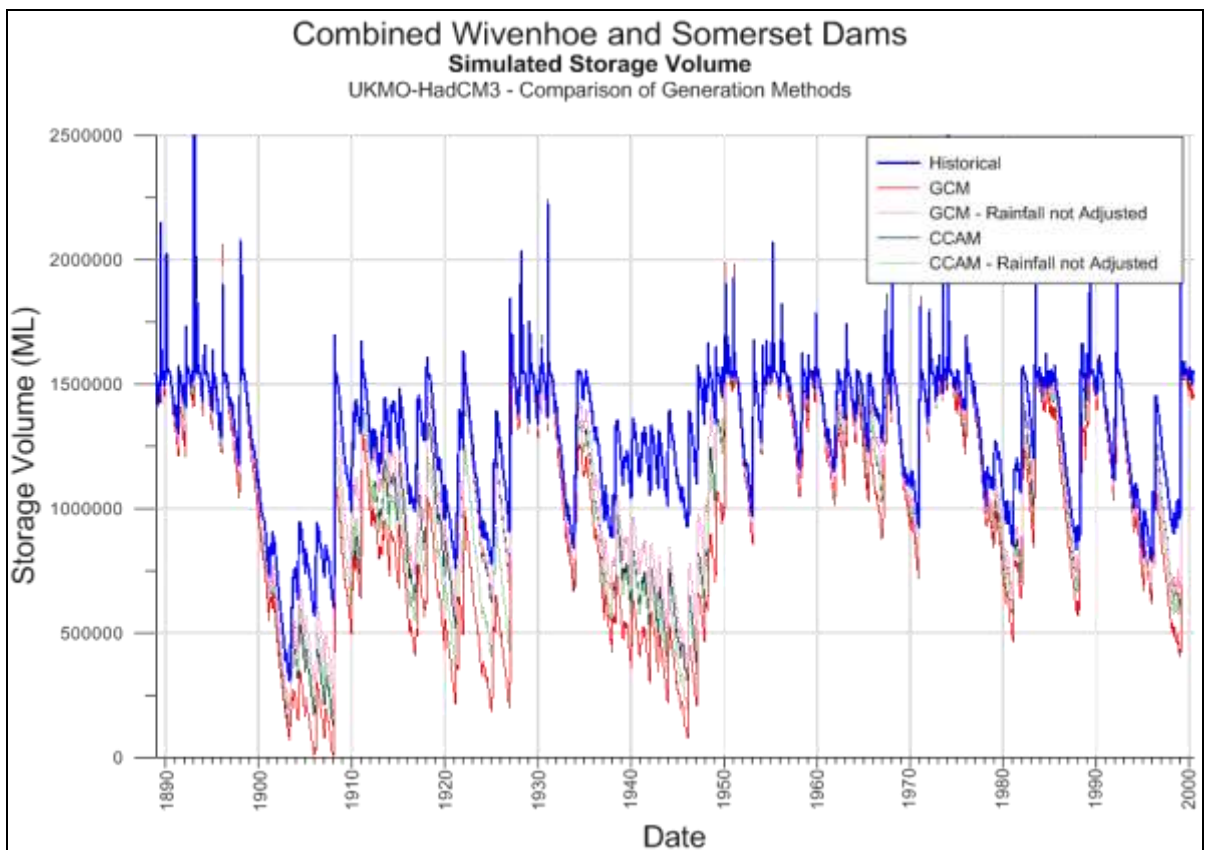


Figure G.35 Combined Wivenhoe and Somerset Dam Storage Volume – Historical, GCM and CCAM – UKMO HadCM3 (With and Without Rainfall Adjusted).

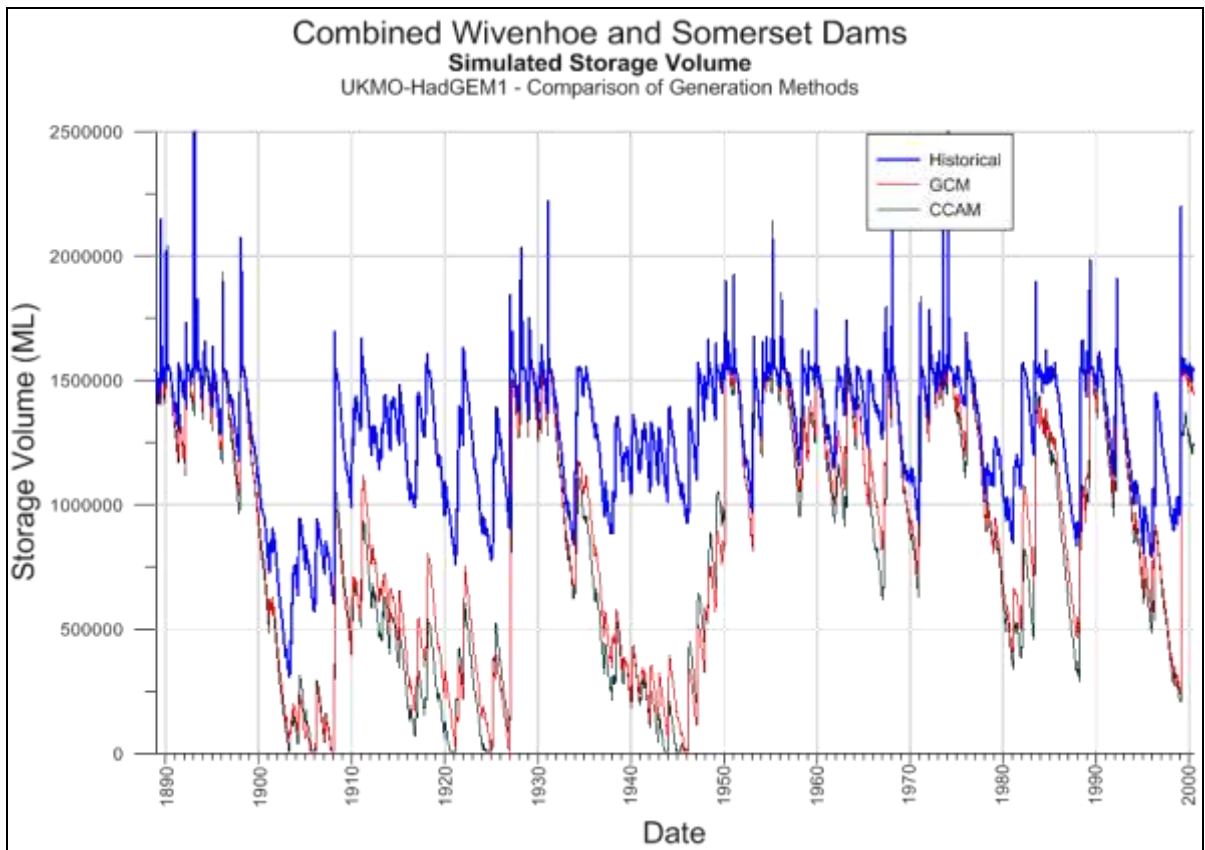


Figure G.36 Combined Wivenhoe and Somerset Dam Storage Volume – Historical, GCM and CCAM – UKMO HadGEM1.

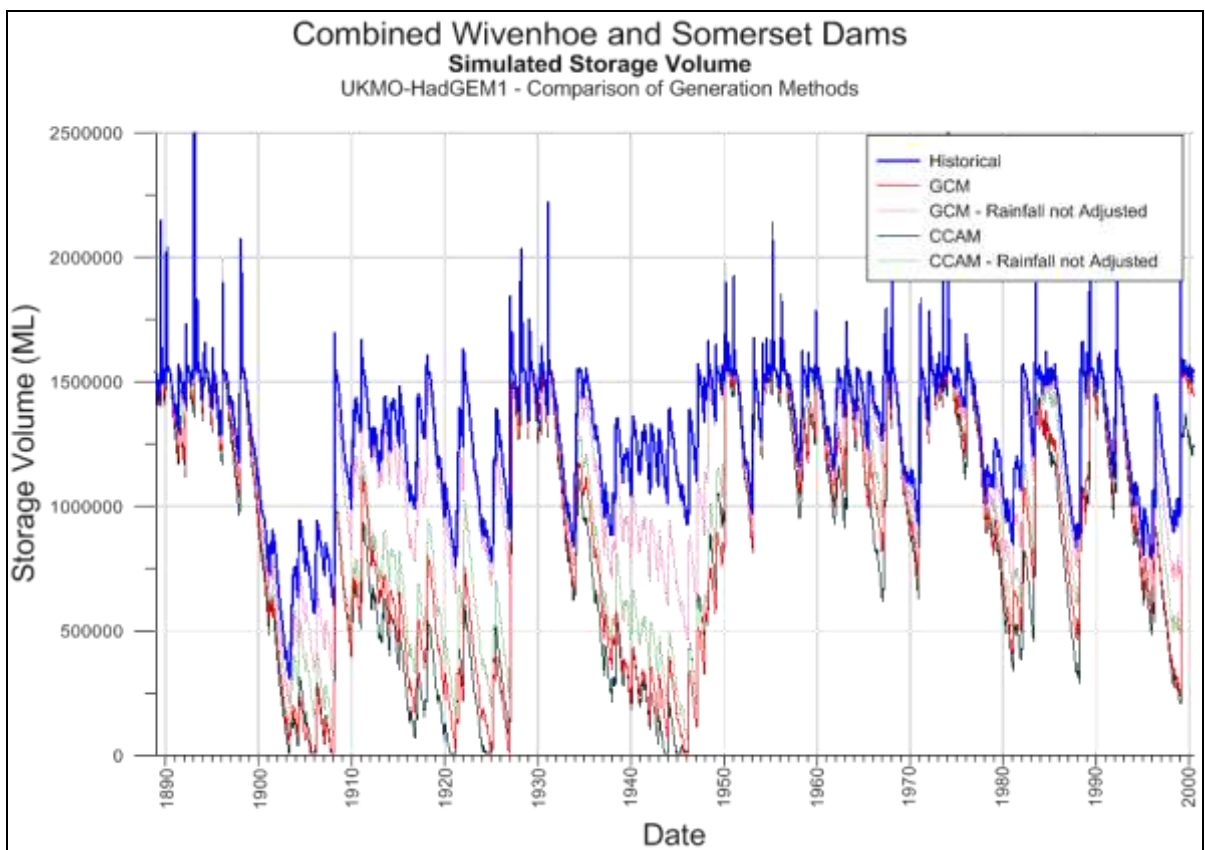


Figure G.37 Combined Wivenhoe and Somerset Dam Storage Volume – Historical, GCM and CCAM – UKMO HadGEM1 (With and Without Rainfall Adjusted).

G.3.2 GCM, CCAM and CCAM PPE1

Table 7.24 Description of Relevant Generation Methods.

Generation Method	Gridsize	Description
GCM	Ranging from 100 to 400km	Global circulation models developed by various research institutes around the world
CCAM	~20km	Original dynamically downscaled models using the Conformal-Cubic Atmospheric Model (CCAM) – downscaled to 20km
CCAM PPE1	~ 8km	Conformal-Cubic Atmospheric Model (CCAM) downscaled with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 8km
CCAM PPE1	~20km	Conformal-Cubic Atmospheric Model (CCAM) downscaled with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 20km

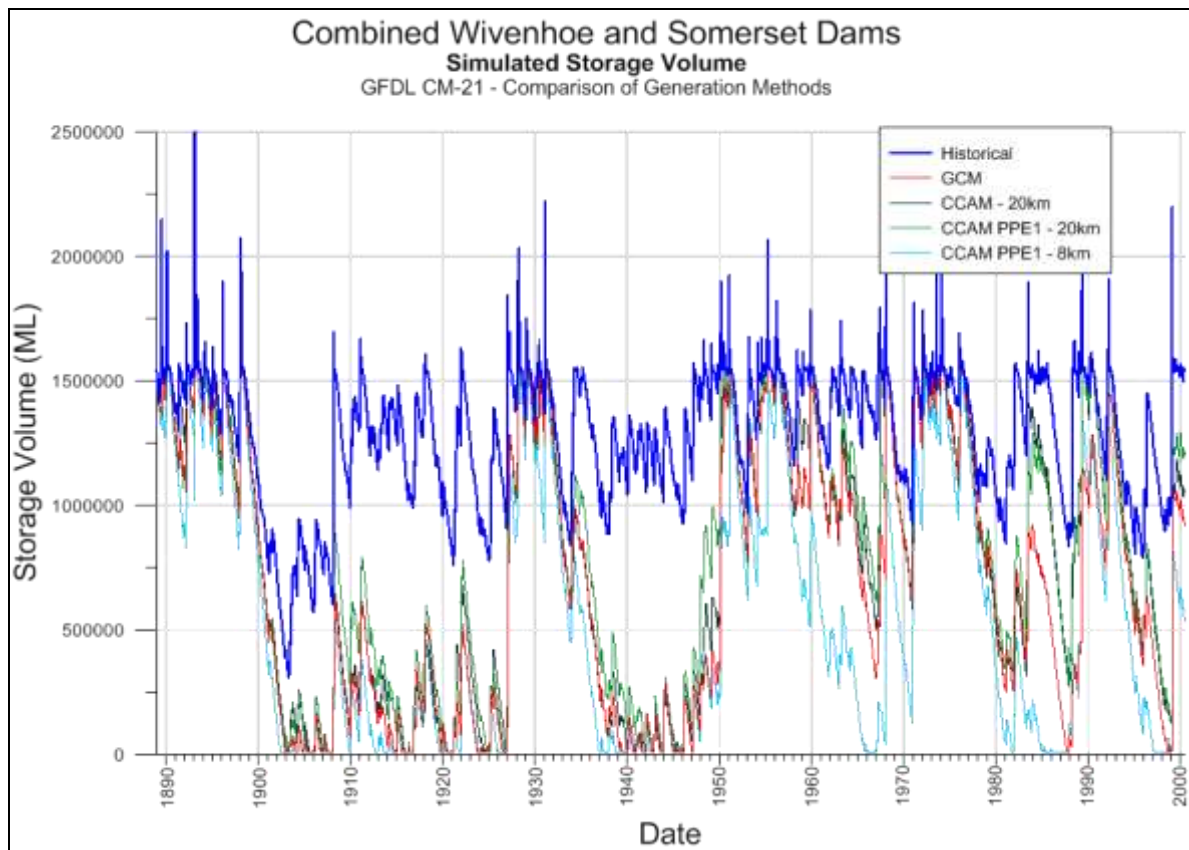


Figure G.38 Combined Wivenhoe and Somerset Dam Storage Volume – Historical, GCM, CCAM and CCAM PPE1 – GFDL CM21.

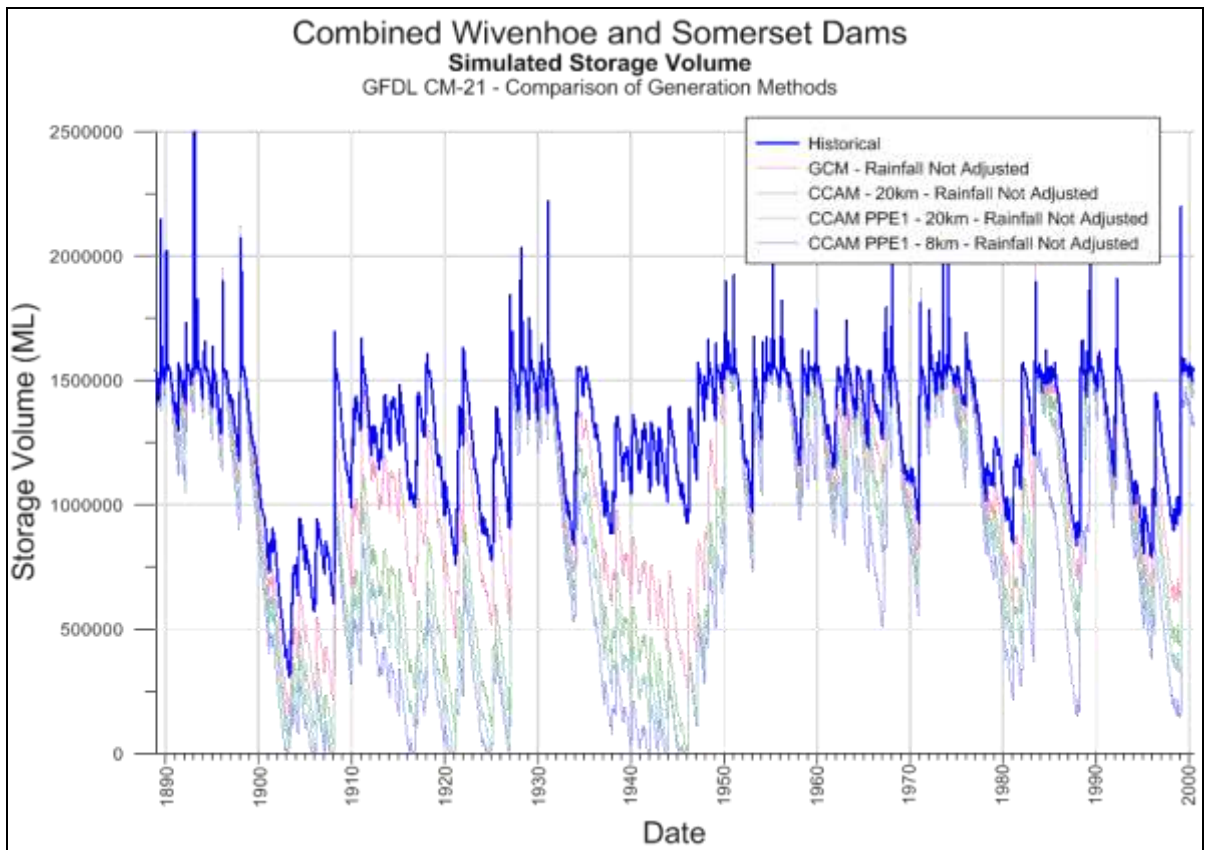


Figure G.39 Combined Wivenhoe and Somerset Dam Storage Volume – Historical, GCM, CCAM and CCAM PPE1 – GFDL CM21 (Rainfall Not Adjusted).

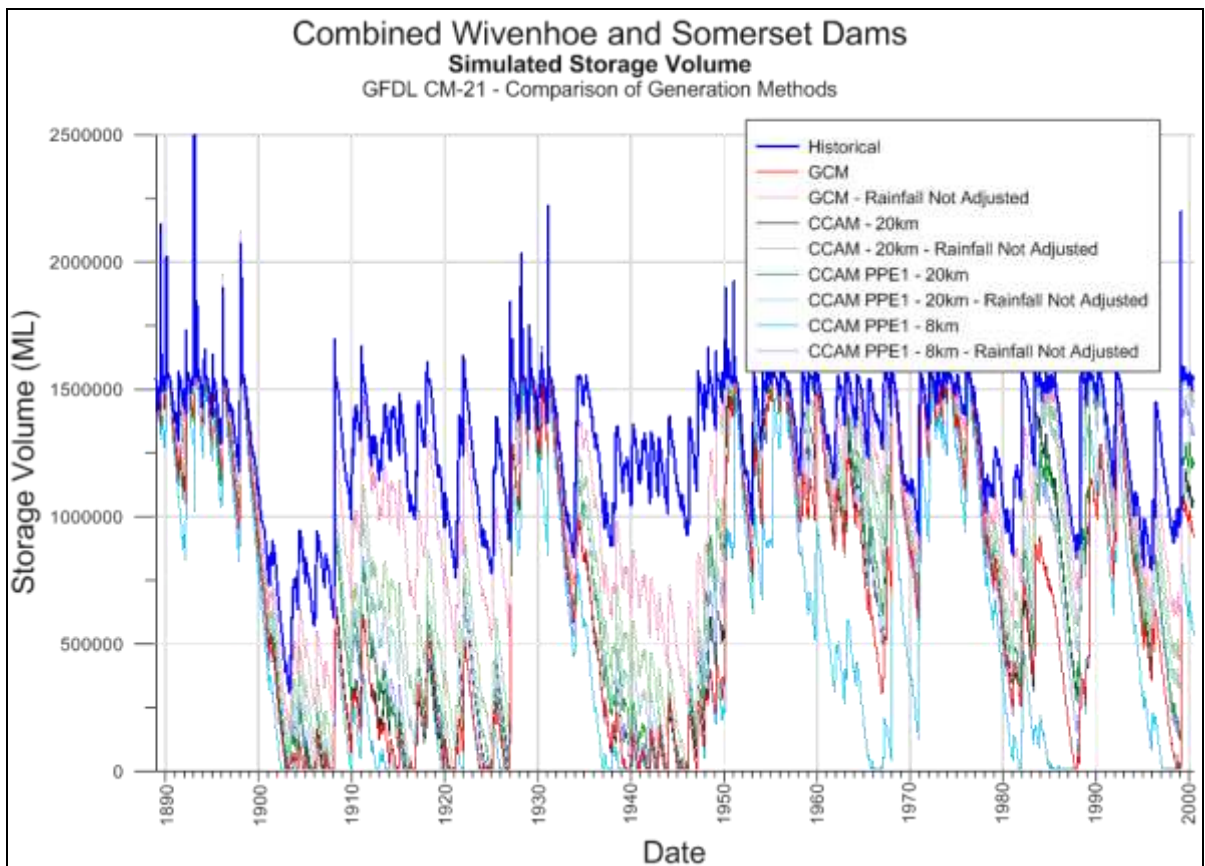


Figure G.40 Combined Wivenhoe and Somerset Dam Storage Volume – Historical, GCM, CCAM and CCAM PPE1 – GFDL CM21 (With and Without Rainfall Adjusted).

APPENDIX H Climate Change Model Output – End of System Flow

H.1 Global Circulation Model Method

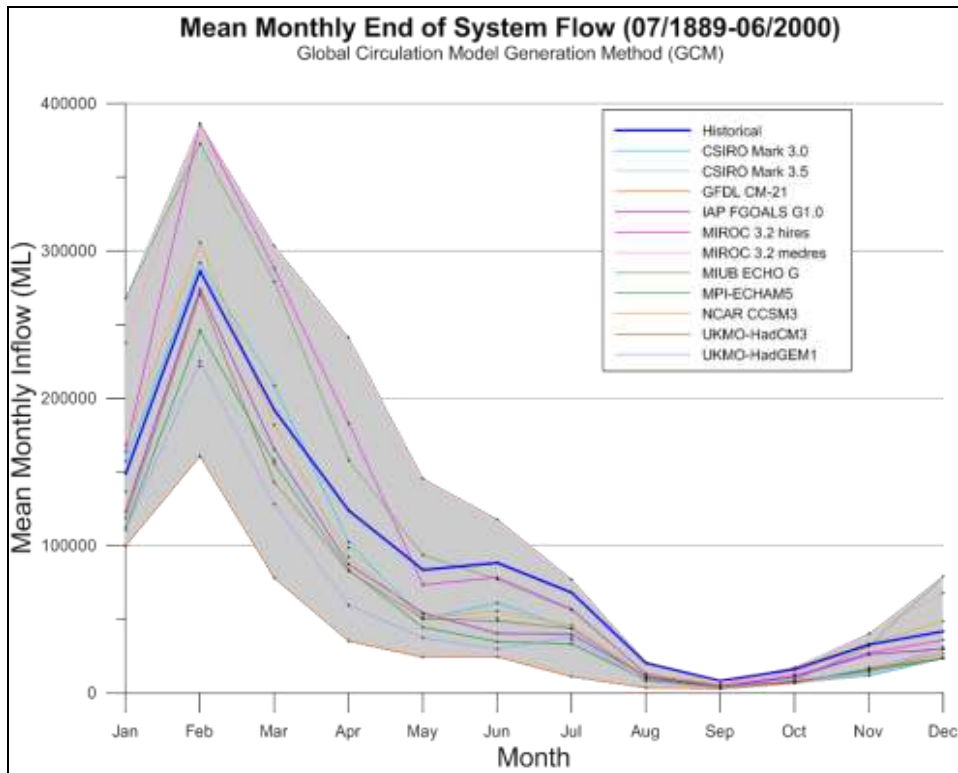


Figure H.1 Mean Monthly End of System Flow (Node 360) – Historical and Range of GCM Climate Model Results.

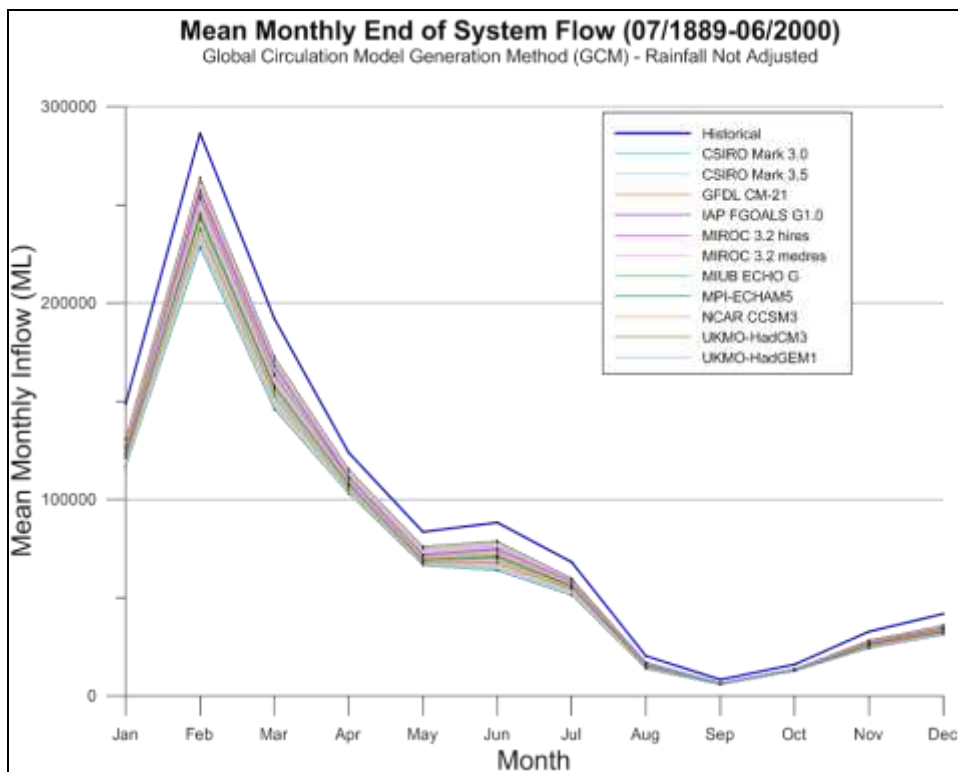


Figure H.2 Mean Monthly End of System Flow (Node 360) – Historical and Range of GCM Climate Model Results (Rainfall Not Adjusted).

H.2 Downscaled Generation Method

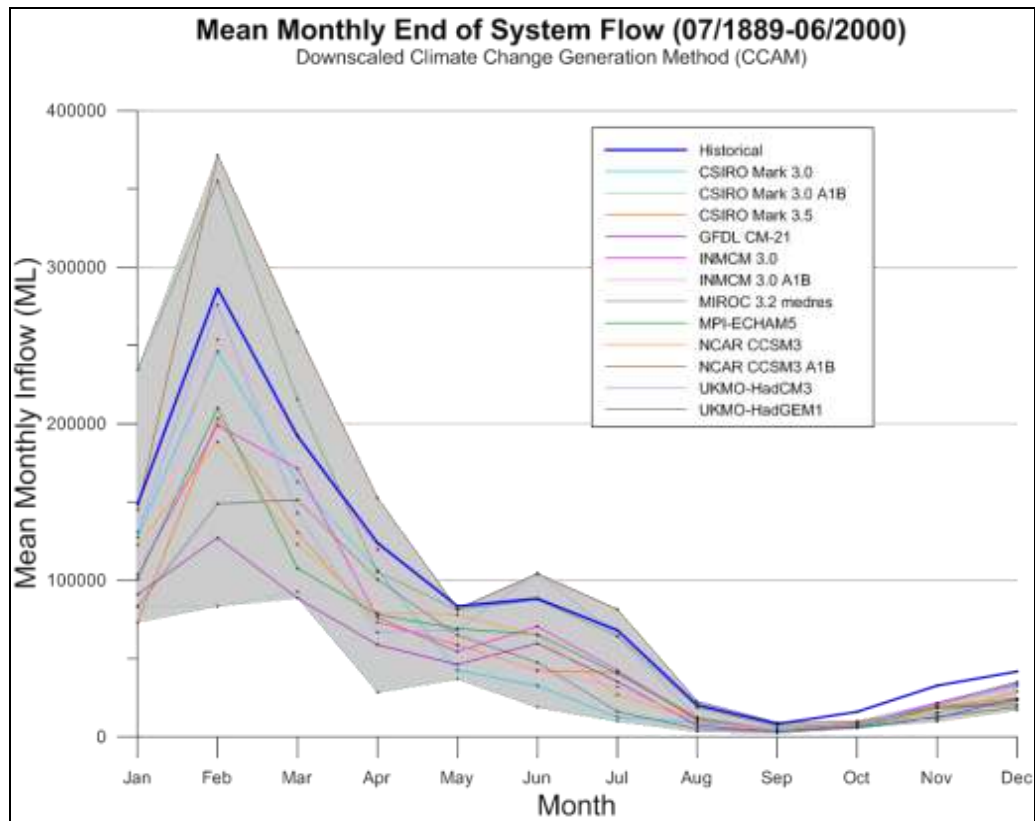


Figure H.3 Mean Monthly End of System Flow (Node 360) – Historical and Range of CCAM Climate Model Results.

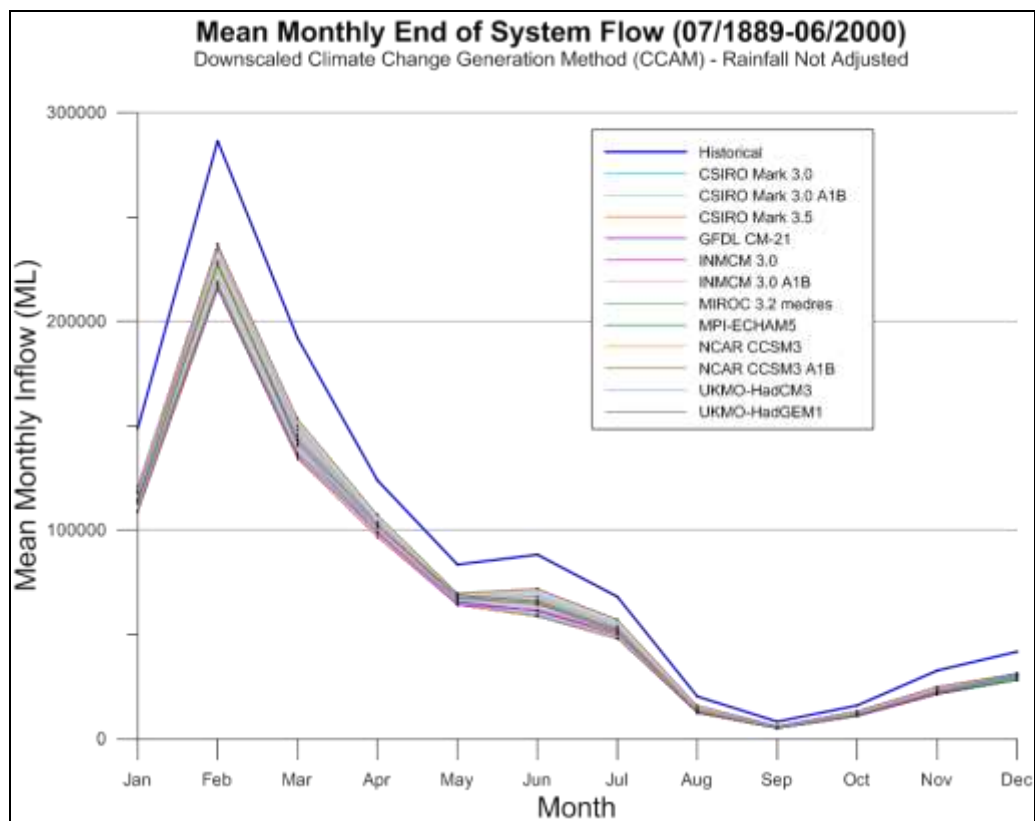


Figure H.4 Mean Monthly End of System Flow (Node 360) – Historical and Range of CCAM Climate Model Results (Rainfall Not Adjusted).

H.3 Comparison of Generation Methods

H.3.1 GCM and CCAM

Table 7.25 Description of Relevant Generation Methods.

Generation Method	Gridsize	Description
GCM	Ranging from 100 to 400km	Global circulation models developed by various research institutes around the world
CCAM	~20km	Original dynamically downscaled models using the Conformal-Cubic Atmospheric Model (CCAM) – downscaled to 20km

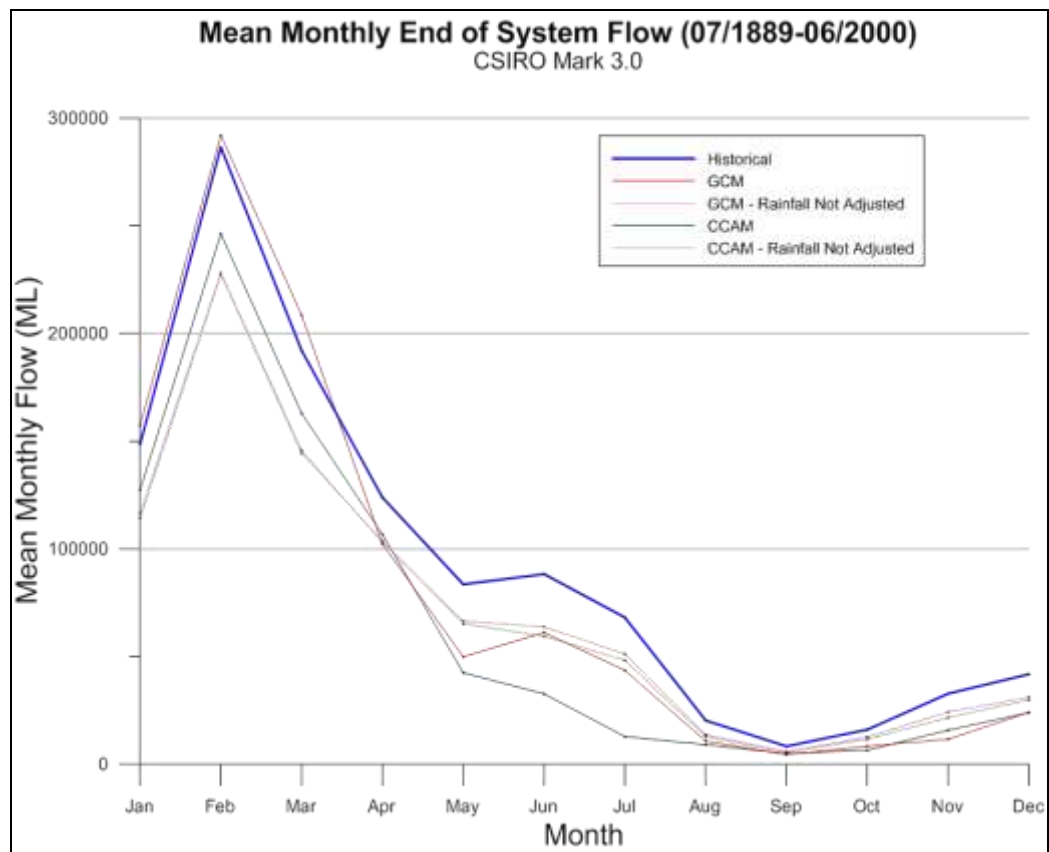


Figure H.5 Mean Monthly End of System Flow (Node 360) – Historical, GCM and CCAM – CSIRO Mark 3.0 (With and Without Rainfall Adjusted).

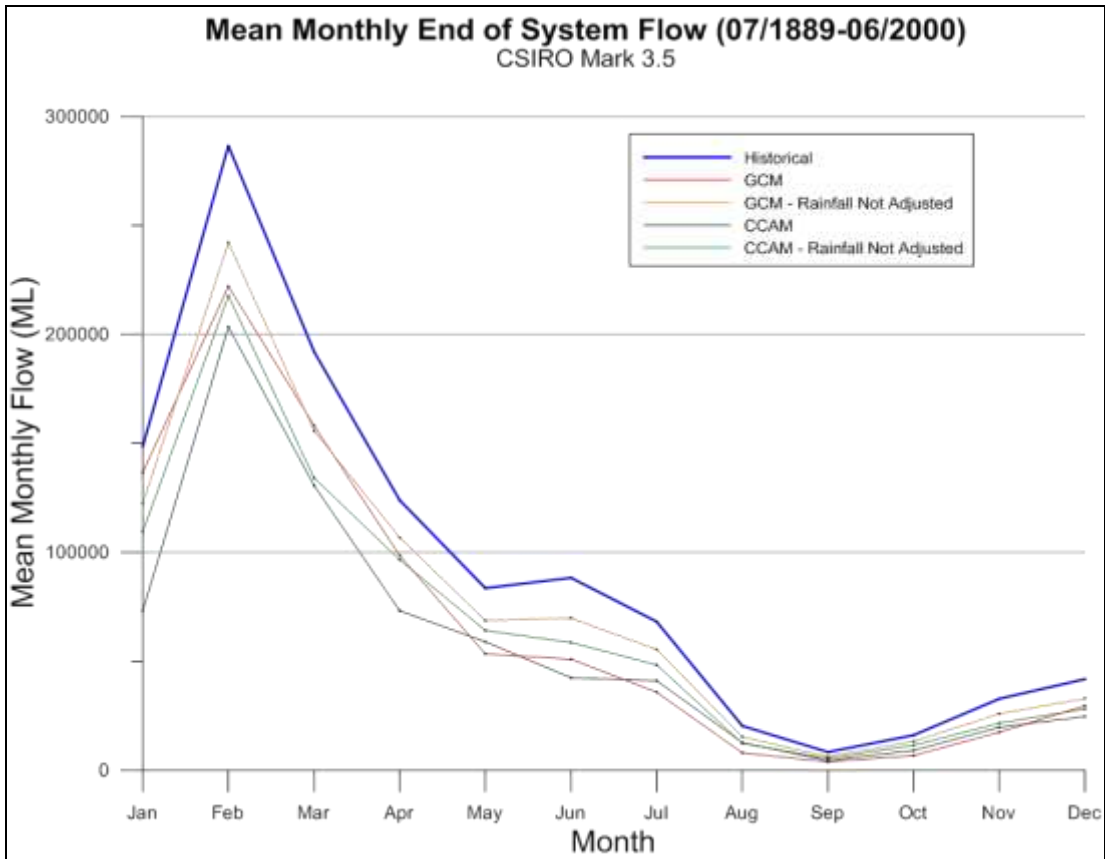


Figure H.6 Mean Monthly End of System Flow (Node 360) – Historical, GCM and CCAM – CSIRO Mark 3.5 (With and Without Rainfall Adjusted).

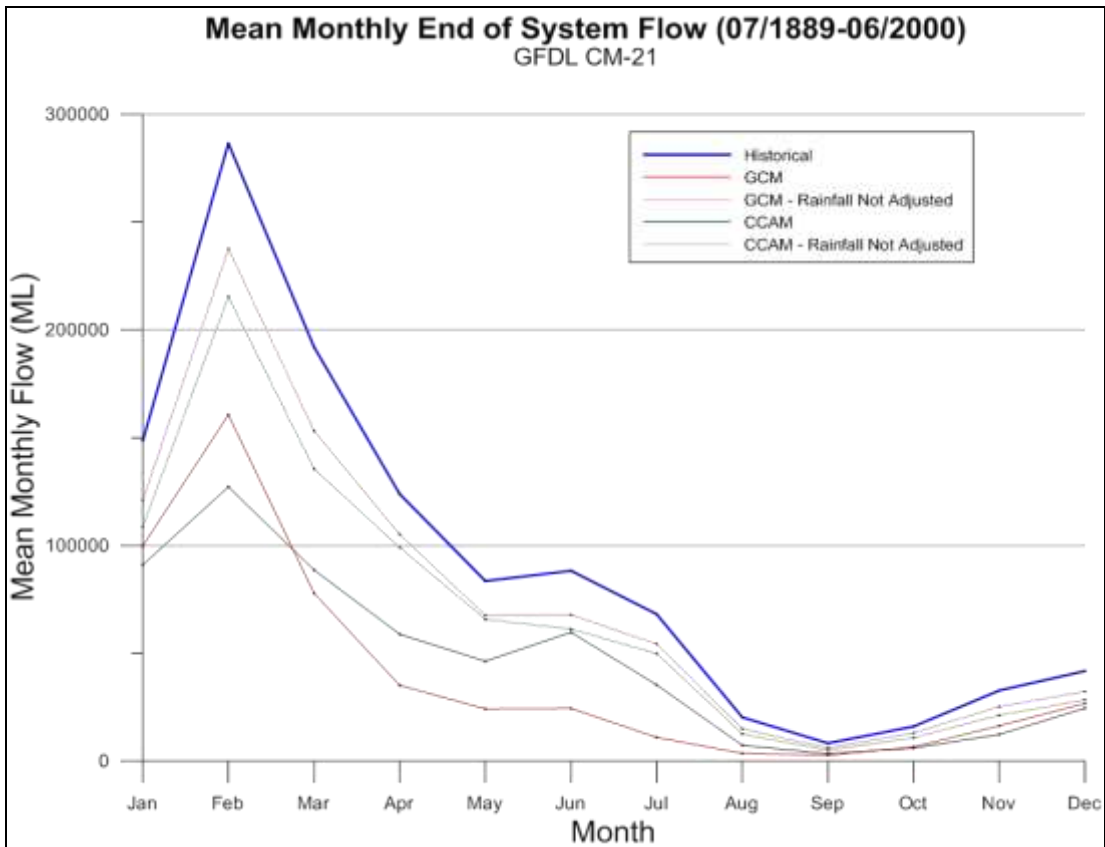


Figure H.7 Mean Monthly End of System Flow (Node 360) – Historical, GCM and CCAM – GFDL CM21 (With and Without Rainfall Adjusted).

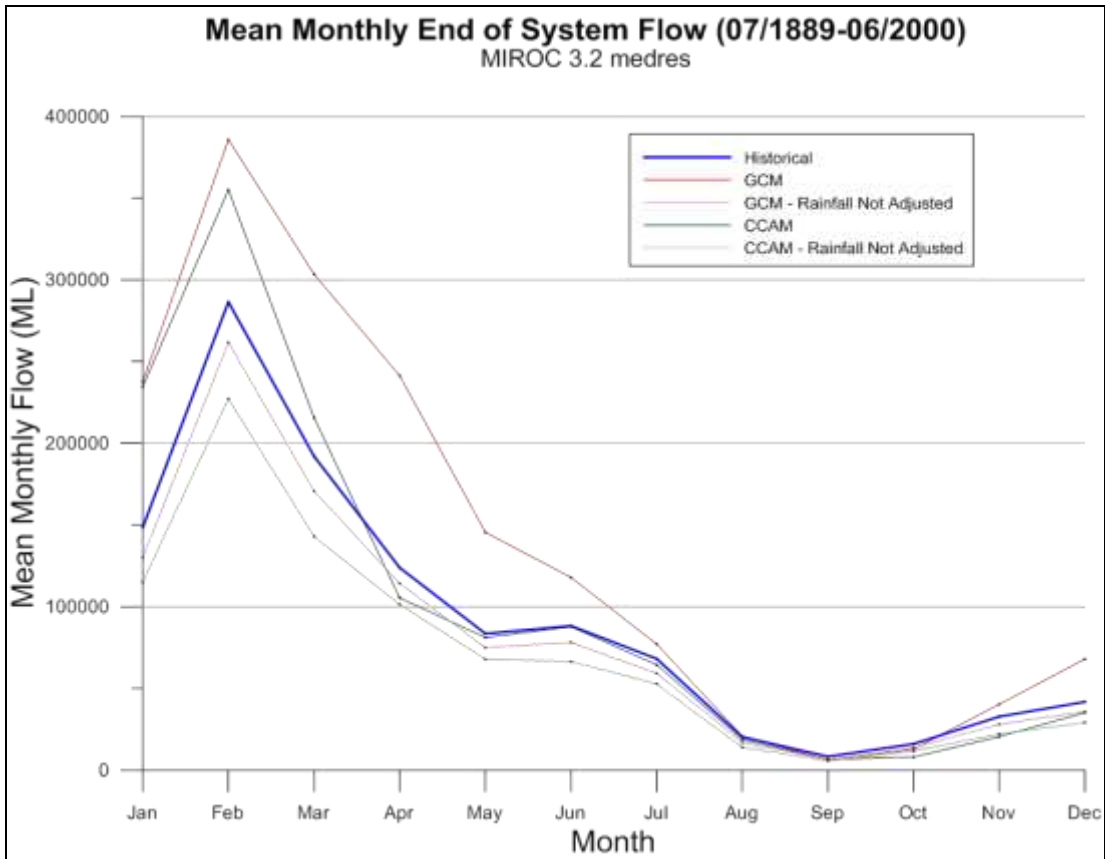


Figure H.8 Mean Monthly End of System Flow (Node 360) – Historical, GCM and CCAM – MIROC 3.2 medres (With and Without Rainfall Adjusted).

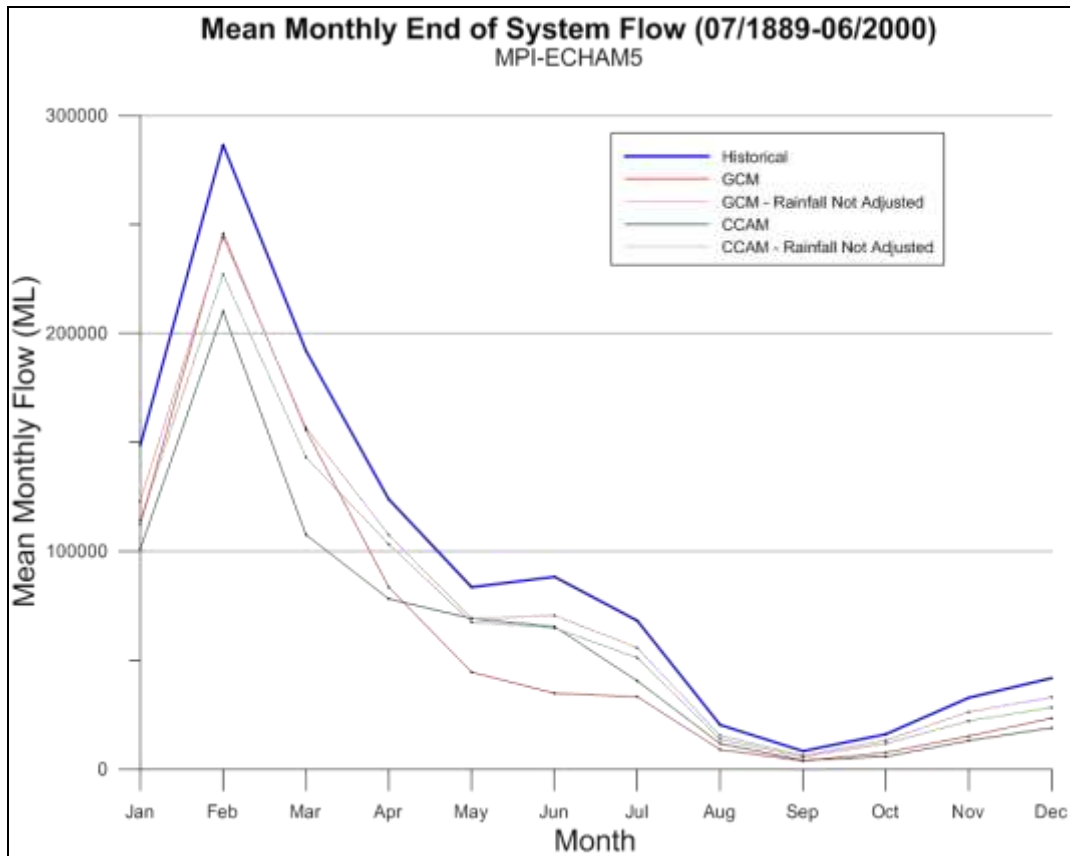


Figure H.9 Mean Monthly End of System Flow (Node 360) – Historical, GCM and CCAM – MPI ECHAM5 (With and Without Rainfall Adjusted).

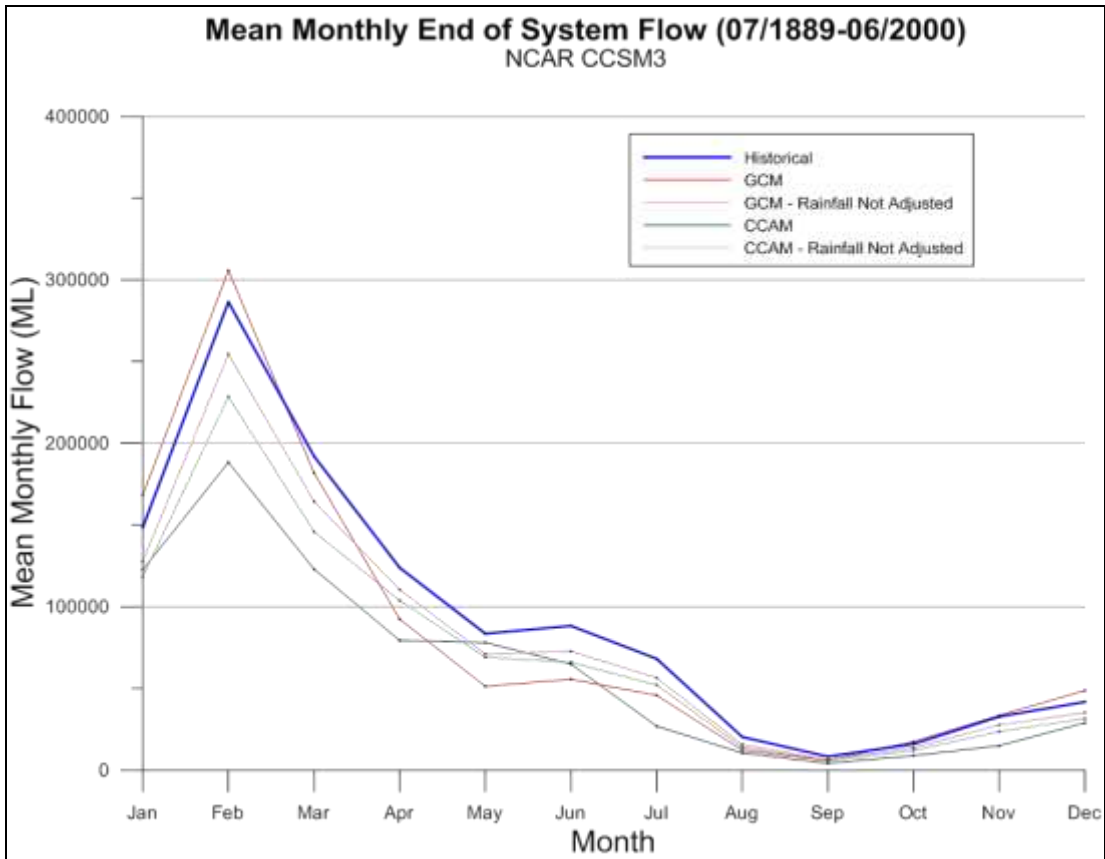


Figure H.10 Mean Monthly End of System Flow (Node 360) – Historical, GCM and CCAM – NCAR CCSM3 (With and Without Rainfall Adjusted).

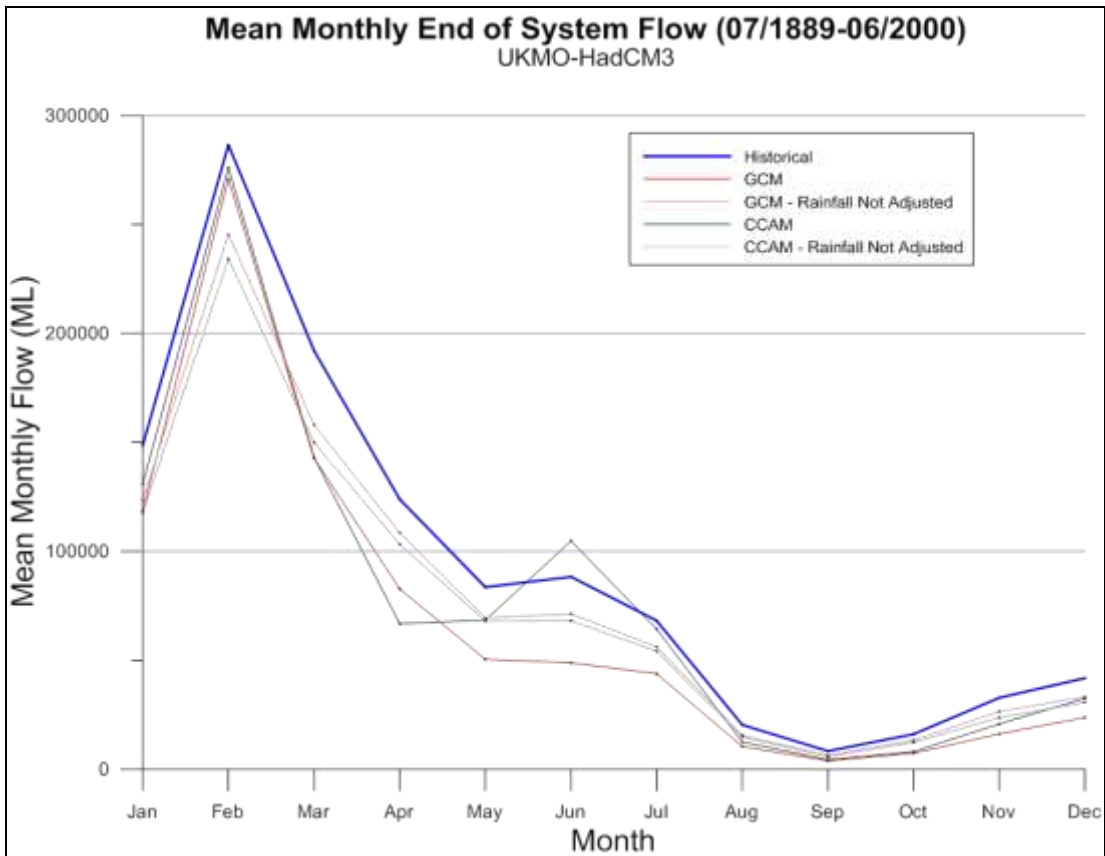


Figure H.11 Mean Monthly End of System Flow (Node 360) – Historical, GCM and CCAM – UKMO HadCM3 (With and Without Rainfall Adjusted).

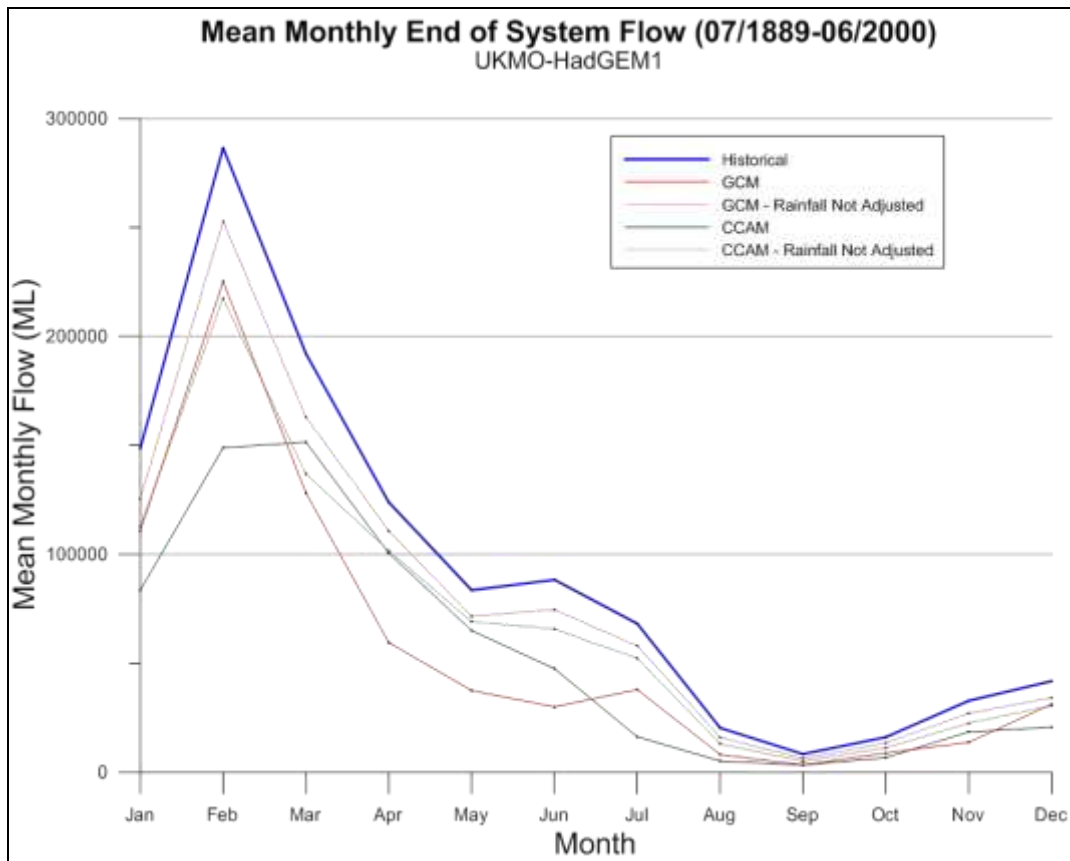


Figure H.12 Mean Monthly End of System Flow (Node 360) – Historical, GCM and CCAM – UKMO HadGEM1 (With and Without Rainfall Adjusted).

H.3.2 GCM, CCAM and CCAM PPE1

Table 7.26 Description of Relevant Generation Methods.

Generation Method	Gridsize	Description
GCM	Ranging from 100 to 400km	Global circulation models developed by various research institutes around the world
CCAM	~20km	Original dynamically downscaled models using the Conformal-Cubic Atmospheric Model (CCAM) – downscaled to 20km
CCAM PPE1	~ 8km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 8km
CCAM PPE1	~20km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 20km

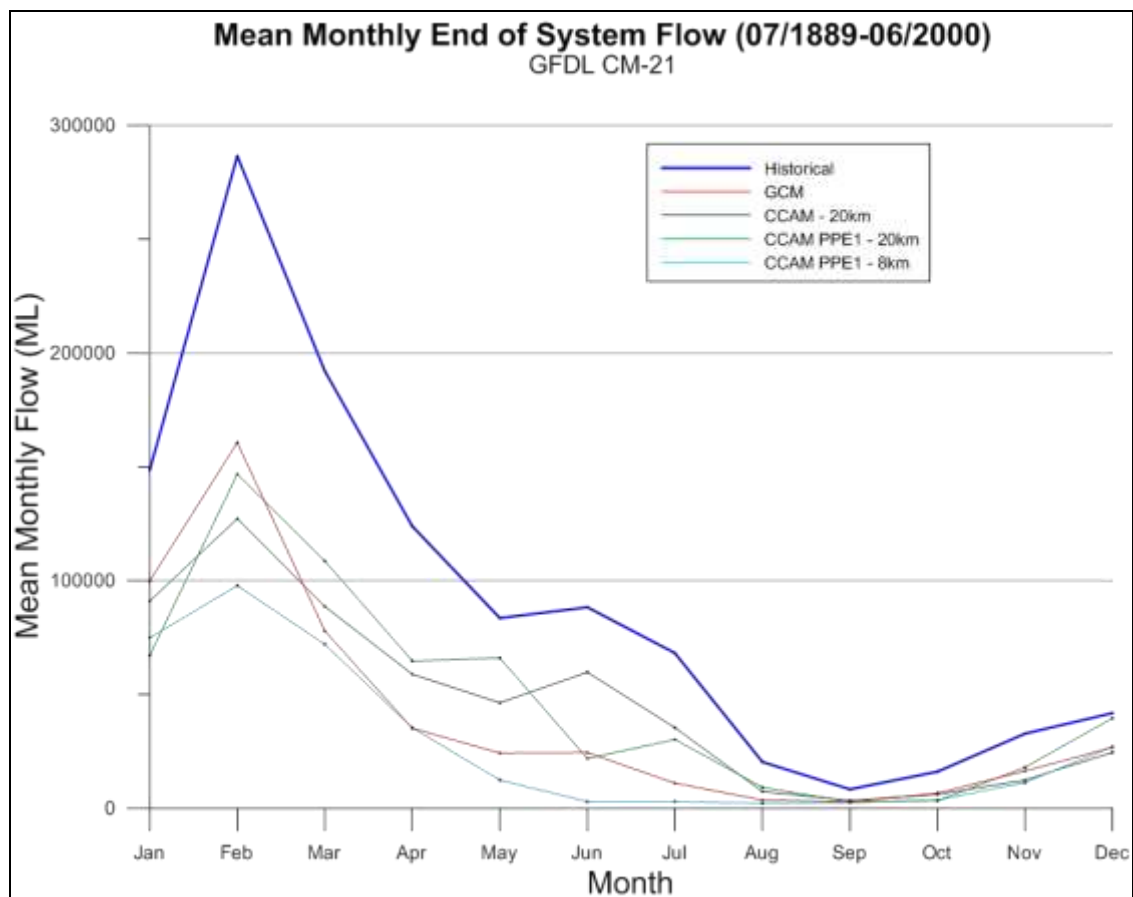


Figure H.13 Mean Monthly End of System Flow (Node 360) – Historical, GCM, CCAM and CCAM PPE1 – GFDL CM21.

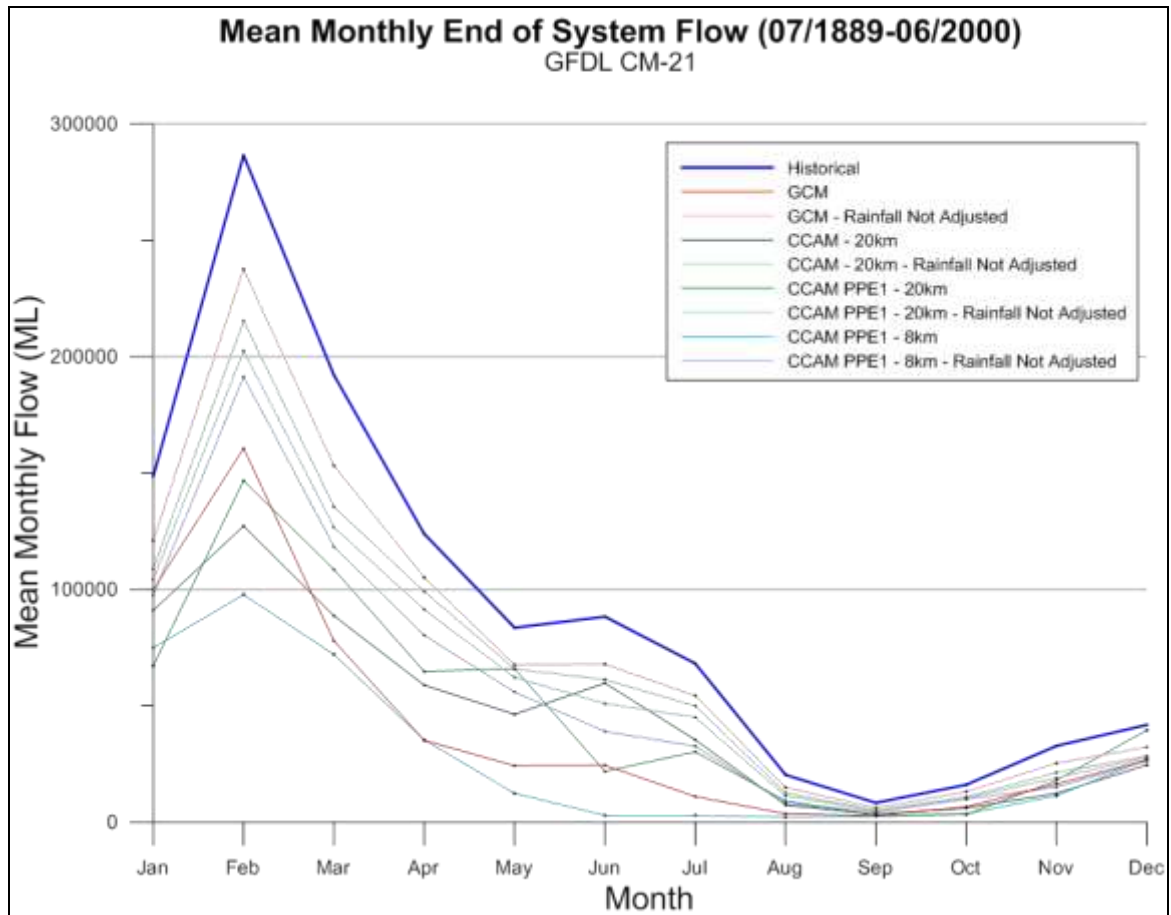


Figure H.14 Mean Monthly End of System Flow (Node 360) – Historical, GCM, CCAM and CCAM PPE1 – GFDL CM21 (With and Without Rainfall Adjusted).

APPENDIX I Level of Service Output – Storage Plots and Statistics

I.1 Global Circulation Model Method

Table 7.27 Average Recurrence Interval of Years Where Combined Storage (Wivenhoe and Somerset Dams) Falls below Specified Trigger Levels (Level of Service) – GCM.

Global Circulation Models	Trigger Level in Combined Storage Wivenhoe and Somerset Dams			
	Dead Storage Volume	25%	50%	75%
	8,886ML	386,000ML	773,000ML	1,159,000ML
Historical	>111.0	111.0	12.3	2.1
CSIRO Mark 3.0	>111.0	13.9	3.2	1.5
CSIRO Mark 3.5	>111.0	6.9	2.3	1.4
GFDL CM21	4.6	2.1	1.6	1.3
IAP FGOALS G1.0	>111.0	13.9	2.8	1.5
MIROC 3.2 hires	>111.0	55.5	13.9	2.4
MIROC 3.2 medres	>111.0	>111.0	37.0	3.6
MIUB ECHO G	>111.0	>111.0	18.5	2.8
MPI ECHAM5	37.0	4.4	2.2	1.4
NCAR CCSM3	>111.0	27.8	6.9	1.8
UKMO HadCM3	55.5	5.8	2.2	1.4
UKMO HadGEM1	22.2	3.6	2.0	1.4

Table 7.28 Average Recurrence Interval of Years Where Combined Storage (Wivenhoe and Somerset Dams) Falls below Specified Trigger Levels (Level of Service) – GCM (Rainfall Not Adjusted).

Global Circulation Models (Rainfall Not Adjusted)	Trigger Level in Combined Storage Wivenhoe and Somerset Dams			
	Dead Storage Volume	25%	50%	75%
	8,886ML	386,000ML	773,000ML	1,159,000ML
Historical	>111.0	111.0	12.3	2.1
CSIRO Mark 3.0	>111.0	7.9	2.4	1.4
CSIRO Mark 3.5	>111.0	18.5	3.0	1.6
GFDL CM21	>111.0	15.9	2.9	1.5
IAP FGOALS G1.0	>111.0	27.8	4.4	1.7
MIROC 3.2 hires	>111.0	27.8	4.4	1.7
MIROC 3.2 medres	>111.0	37.0	6.5	1.8
MIUB ECHO G	>111.0	55.5	7.4	1.8
MPI ECHAM5	>111.0	18.5	3.4	1.6
NCAR CCSM3	>111.0	27.8	4.4	1.7
UKMO HadCM3	>111.0	18.5	3.5	1.6
UKMO HadGEM1	>111.0	27.8	4.3	1.7

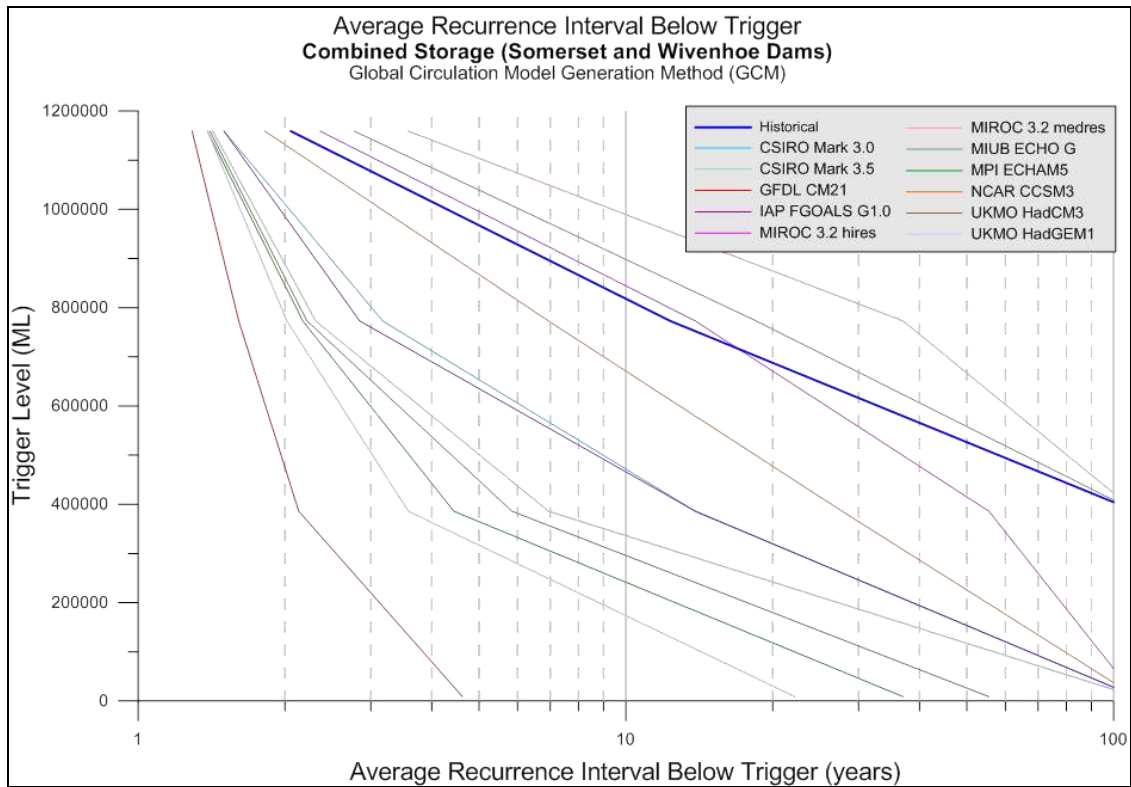


Figure I.1 Average Recurrence Interval Below Specified Trigger Levels - Combined Wivenhoe and Somerset Dams – Historical and GCM Climate Model Results.

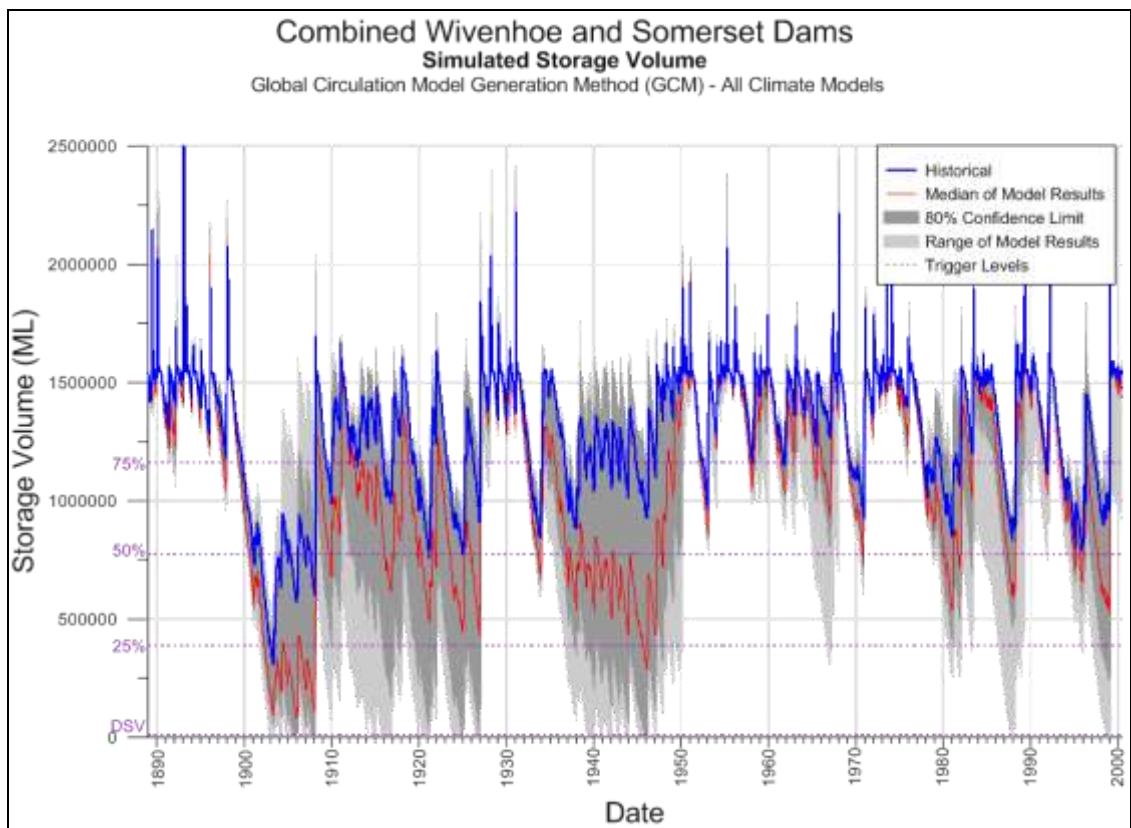


Figure I.2 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and Range of GCM Climate Model Results with Specified Trigger Levels (for All Climate Models).

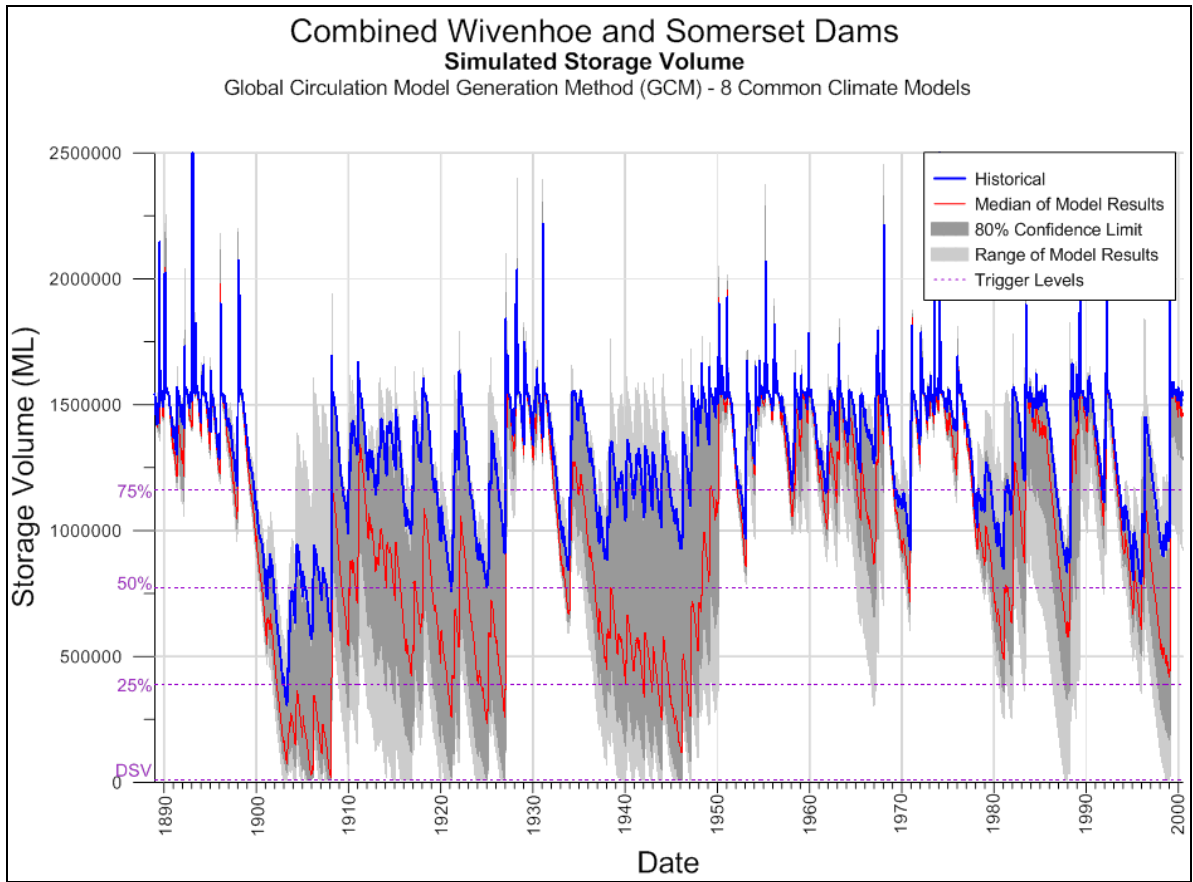


Figure I.3 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and Range of GCM Climate Model Results with Specified Trigger Levels (for 8 Common Climate Models).

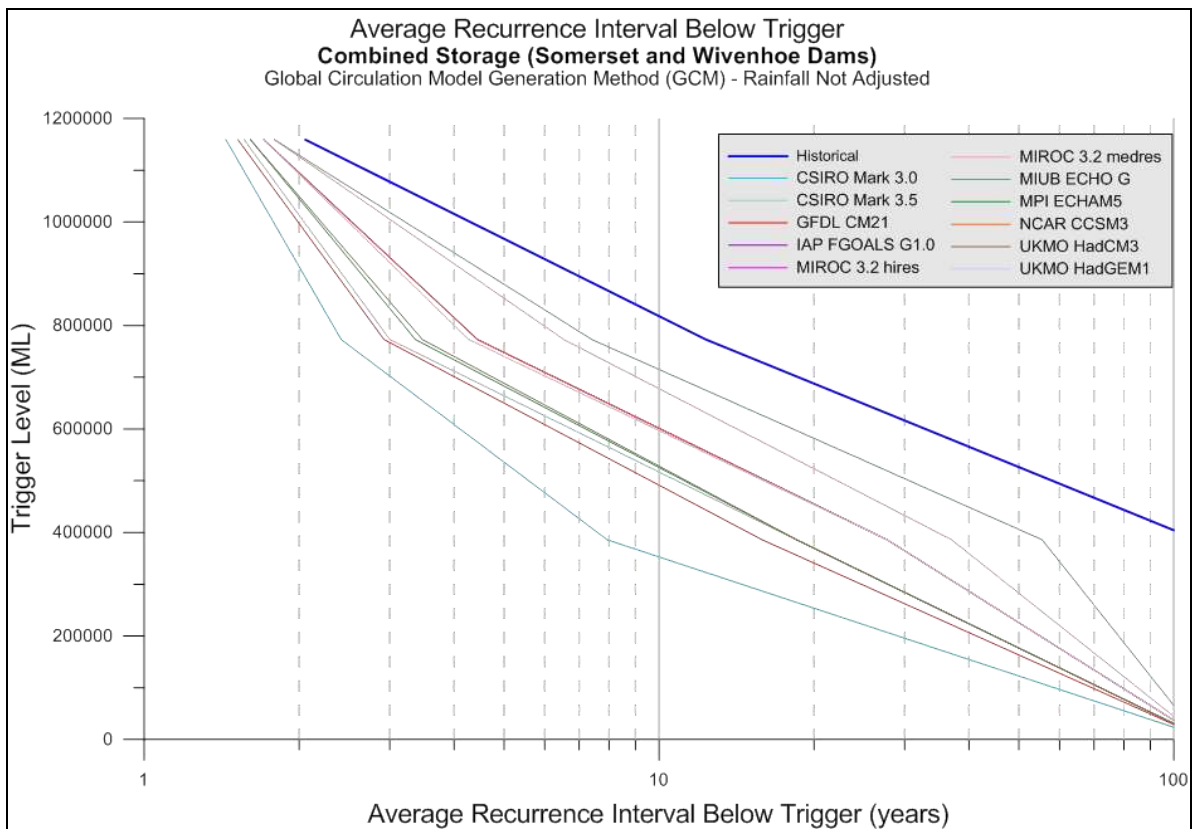


Figure I.4 Average Recurrence Interval Below Specified Trigger Levels - Combined Wivenhoe and Somerset Dams – Historical and GCM Climate Model Results (Rainfall Not Adjusted).

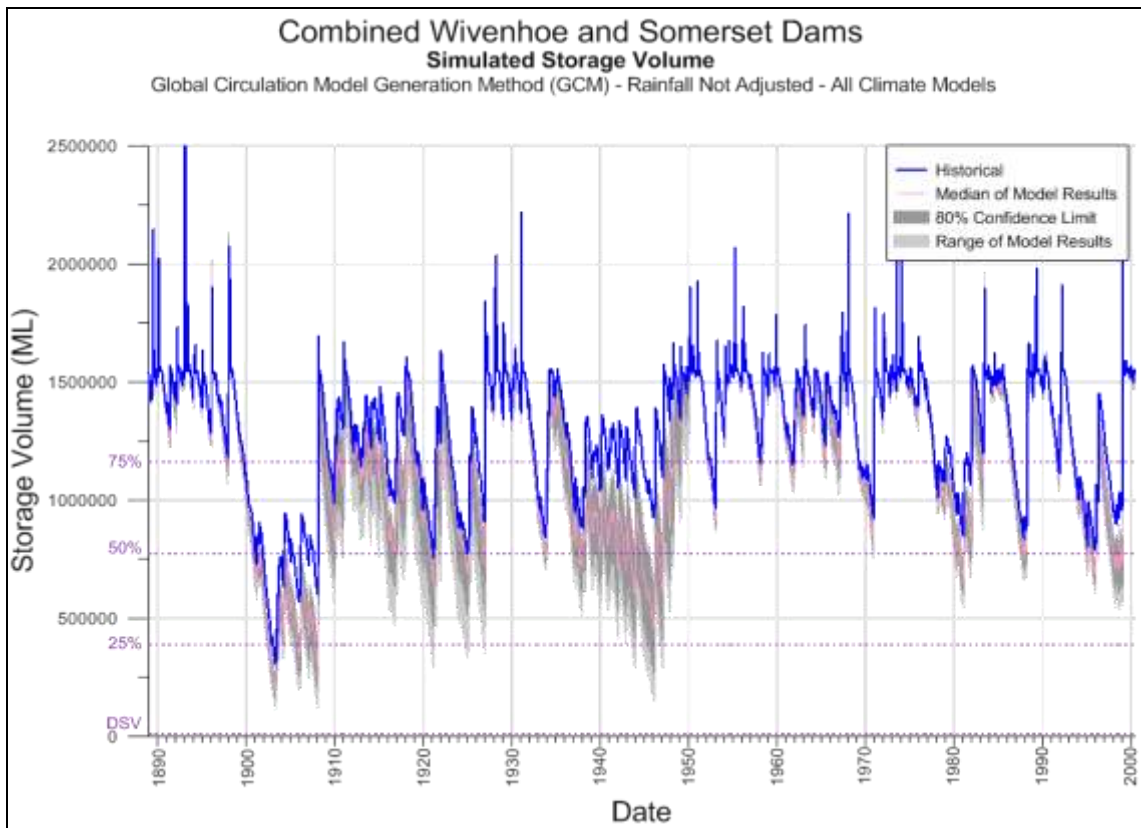


Figure I.5 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and Range of GCM Climate Model Results with Specified Trigger Levels (for All Climate Models) (Rainfall Not Adjusted).

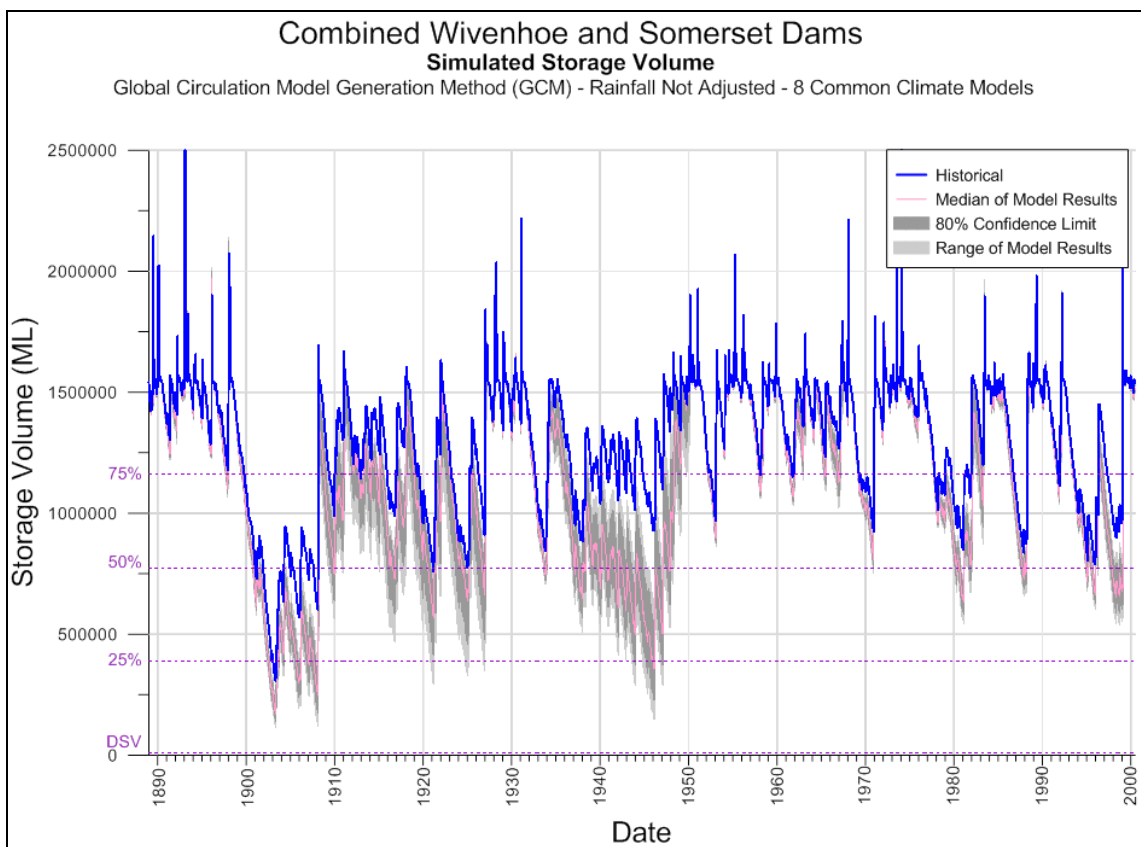


Figure I.6 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and Range of GCM Climate Model Results with Specified Trigger Levels (for 8 Common Climate Models) (Rainfall Not Adjusted).

I.2 Downscaled Generation Method

Table 7.29 Average Recurrence Interval of Years Where Combined Storage (Wivenhoe and Somerset Dams) Falls below Specified Trigger Levels (Level of Service) – CCAM.

Downscaled Climate Models	Trigger Level in Combined Storage Wivenhoe and Somerset Dams			
	Dead Storage Volume	25%	50%	75%
	8,886ML	386,000ML	773,000ML	1,159,000ML
Historical	>111.0	111.0	12.3	2.1
CSIRO Mark 3.0	37.0	3.8	2.1	1.4
CSIRO Mark 3.0 A1B	4.1	2.0	1.6	1.2
CSIRO Mark 3.5	15.9	3.0	2.0	1.4
GFDL CM21	6.2	2.5	1.8	1.3
INMCM 3.0	>111.0	7.9	2.5	1.4
INMCM 3.0 A1B	111.0	6.5	2.5	1.4
MIROC 3.2 medres	>111.0	27.8	6.9	1.7
MPI ECHAM5	13.9	3.0	1.9	1.4
NCAR CCSM3	55.5	3.8	2.1	1.4
NCAR CCSM3 A1B	>111.0	111.0	11.1	2.2
UKMO HadCM3	>111.0	12.3	2.8	1.5
UKMO HadGEM1	12.3	3.1	1.9	1.3

Table 7.30 Average Recurrence Interval of Years Where Combined Storage (Wivenhoe and Somerset Dams) Falls below Specified Trigger Levels (Level of Service) – CCAM (Rainfall Not Adjusted).

Downscaled Climate Models (Rainfall Not Adjusted)	Trigger Level in Combined Storage Wivenhoe and Somerset Dams			
	Dead Storage Volume	25%	50%	75%
	8,886ML	386,000ML	773,000ML	1,159,000ML
Historical	>111.0	111.0	12.3	2.1
CSIRO Mark 3.0	>111.0	6.2	2.2	1.4
CSIRO Mark 3.0 A1B	>111.0	5.6	2.2	1.4
CSIRO Mark 3.5	111.0	4.4	2.1	1.4
GFDL CM21	111.0	4.4	2.1	1.4
INMCM 3.0	>111.0	6.5	2.2	1.4
INMCM 3.0 A1B	>111.0	7.9	2.5	1.5
MIROC 3.2 medres	>111.0	6.9	2.4	1.4
MPI ECHAM5	>111.0	6.5	2.3	1.4
NCAR CCSM3	>111.0	7.9	2.5	1.5
NCAR CCSM3 A1B	>111.0	15.9	2.9	1.5
UKMO HadCM3	>111.0	9.3	2.7	1.5
UKMO HadGEM1	>111.0	5.8	2.2	1.4

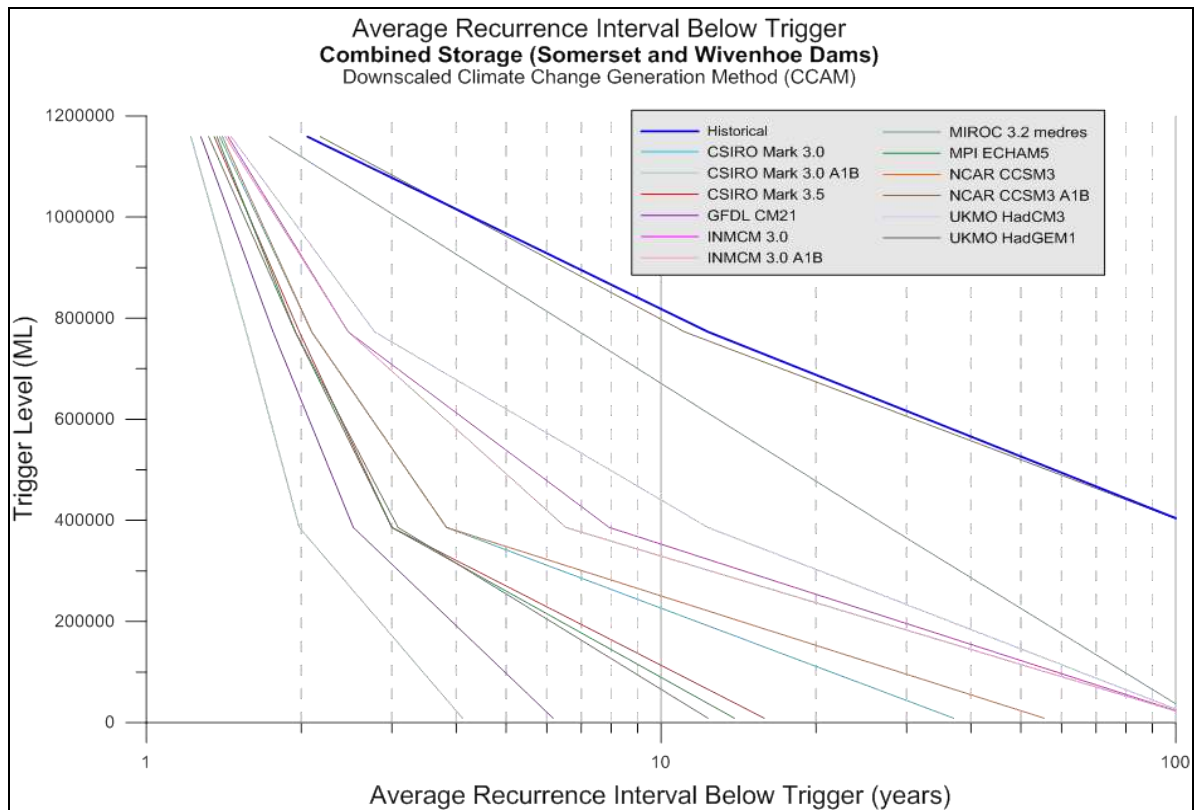


Figure I.7 Average Recurrence Interval Below Specified Trigger Levels - Combined Wivenhoe and Somerset Dams – Historical and CCAM Climate Model Results.

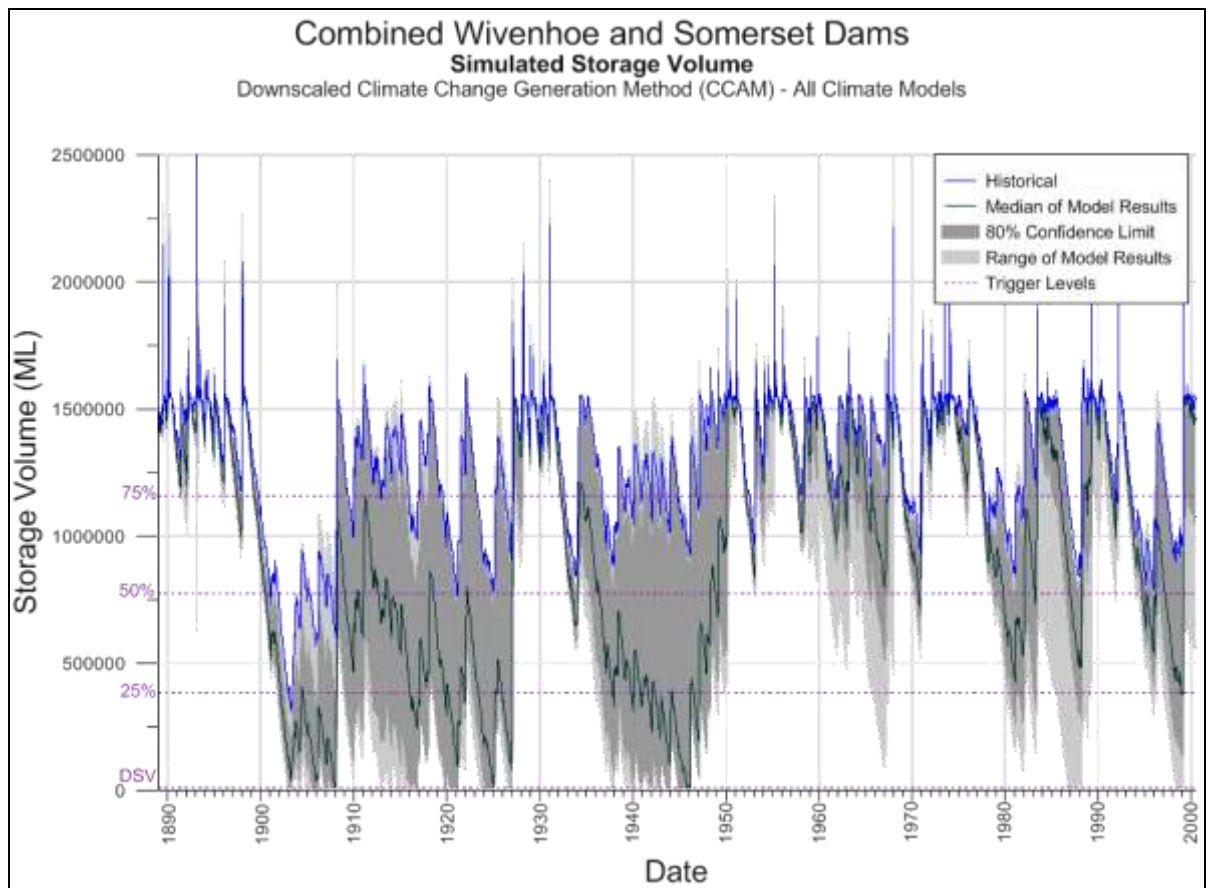


Figure I.8 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and Range of CCAM Climate Model Results with Specified Trigger Levels (for All Climate Models).

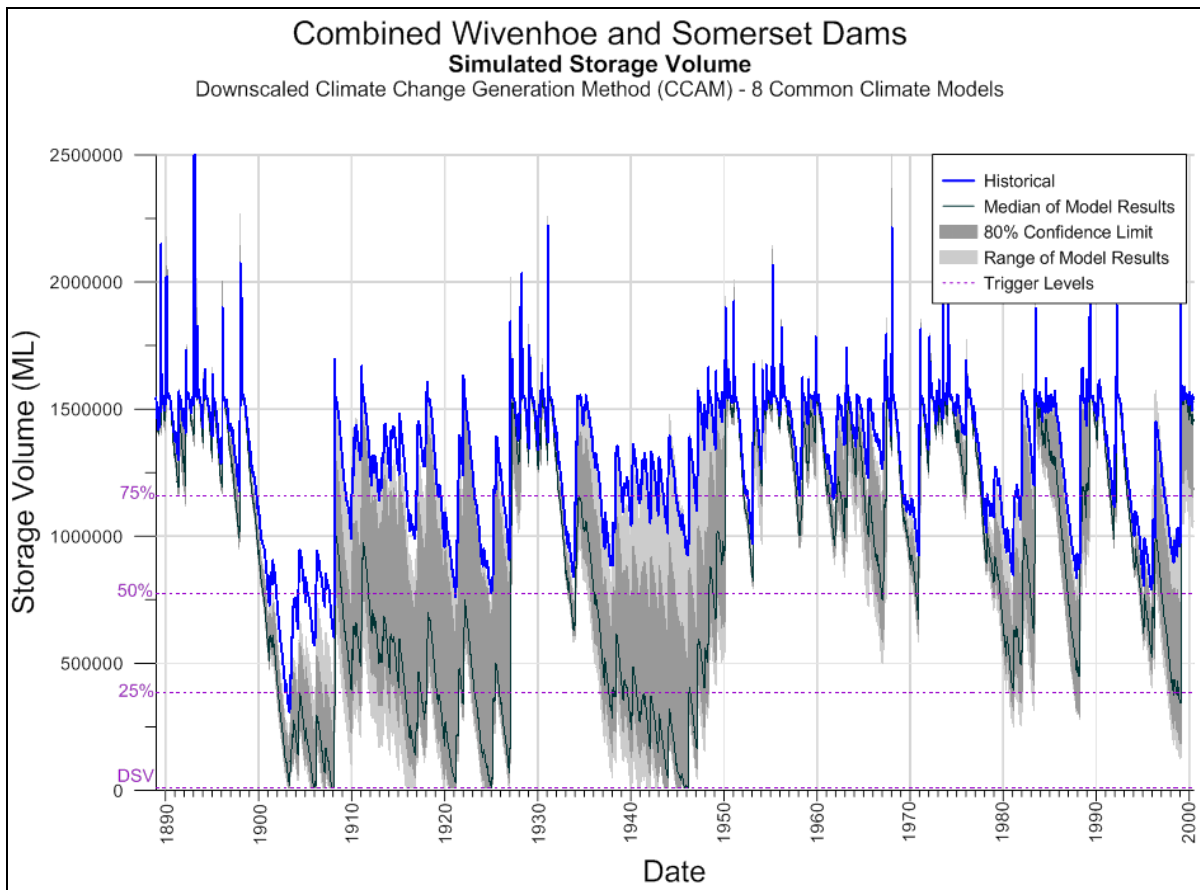


Figure I.9 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and Range of CCAM Climate Model Results with Specified Trigger Levels (for 8 Common Climate Models).

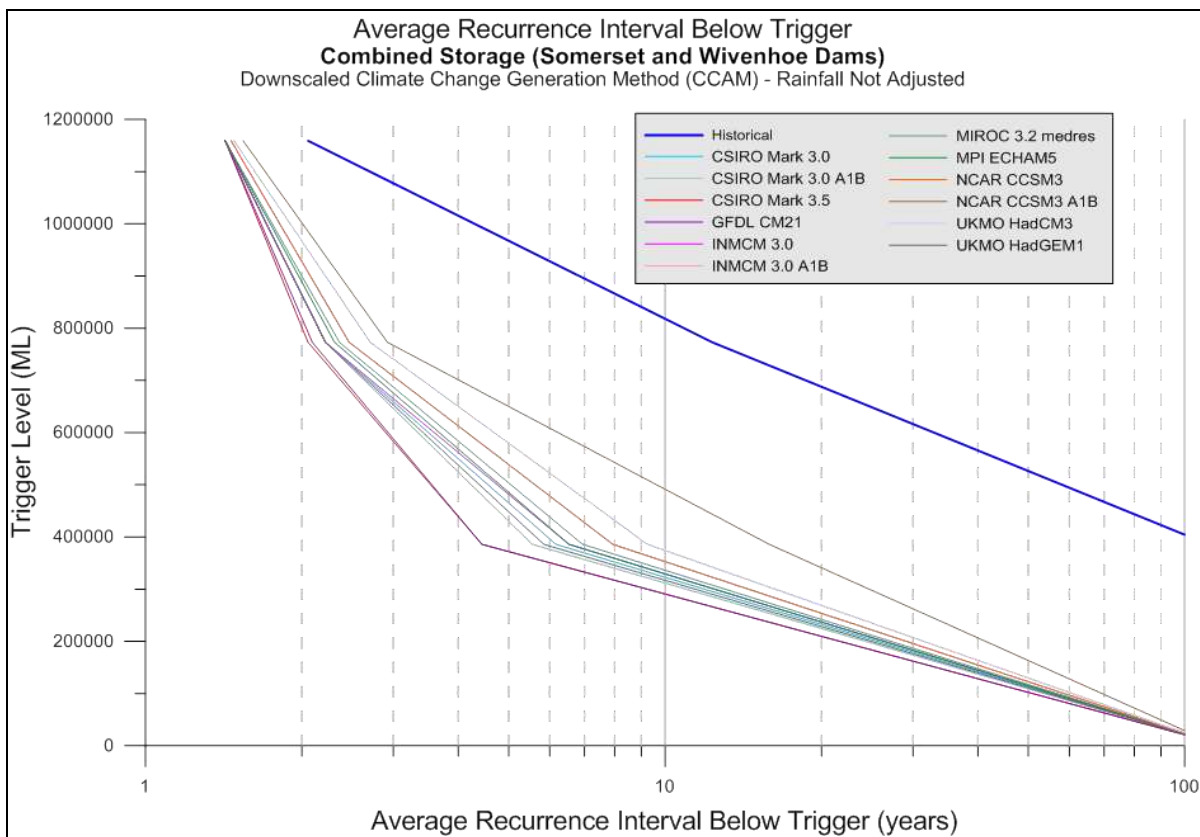


Figure I.10 Average Recurrence Interval Below Specified Trigger Levels - Combined Wivenhoe and Somerset Dams – Historical and CCAM Climate Model Results (Rainfall Not Adjusted).

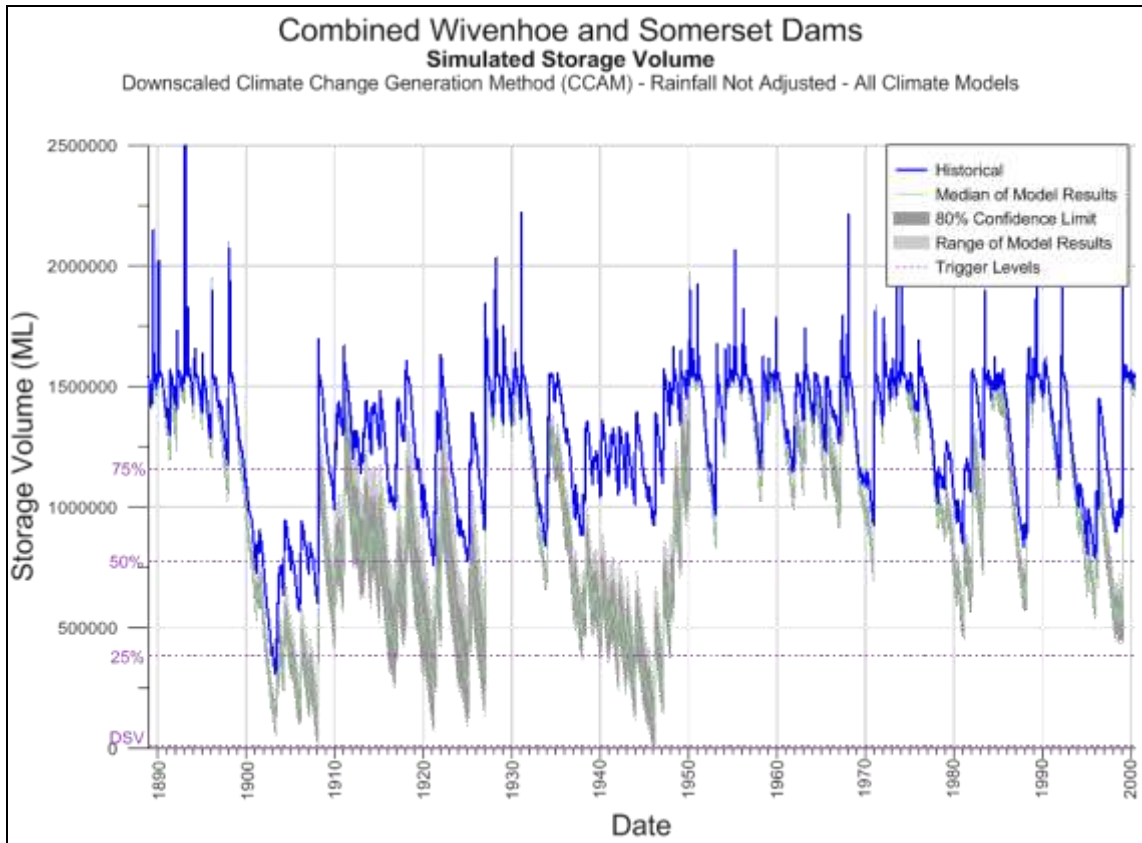


Figure I.11 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and Range of CCAM Climate Model Results with Specified Trigger Levels (for All Climate Models) (Rainfall Not Adjusted).

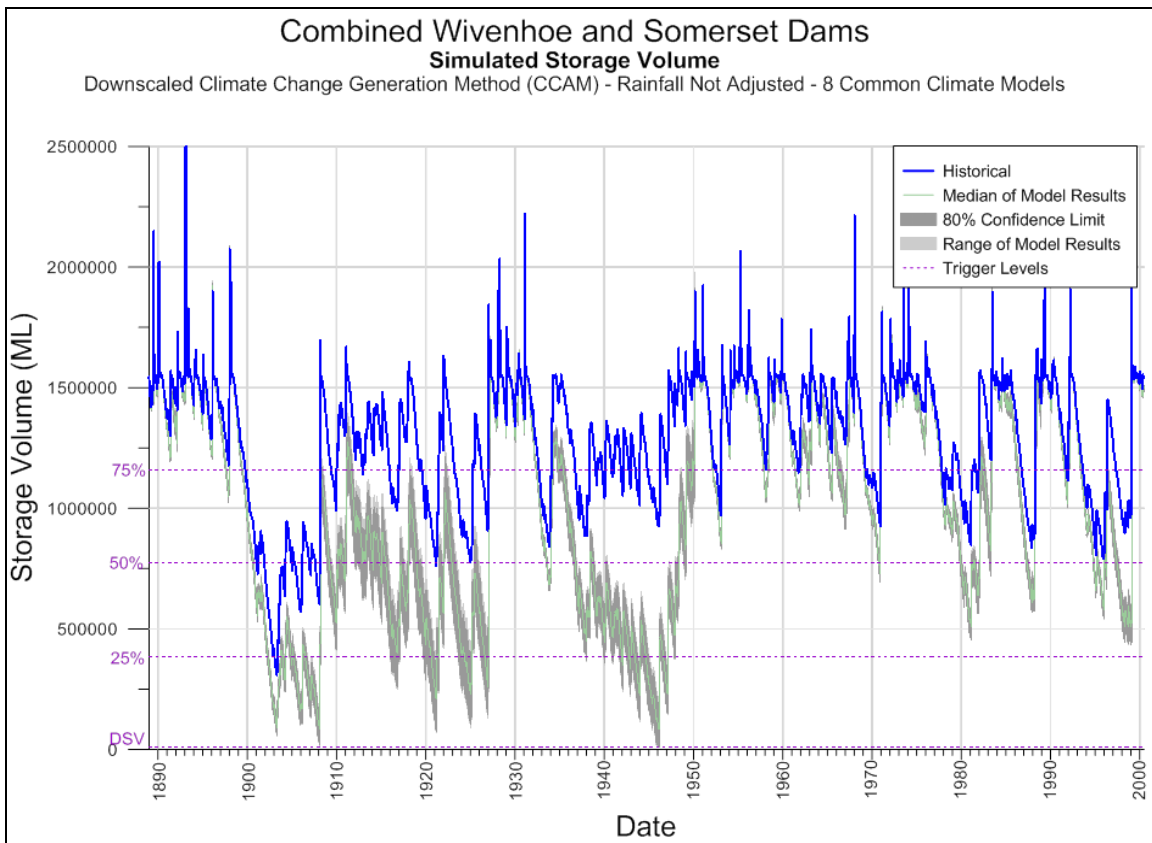


Figure I.12 Combined Wivenhoe and Somerset Dam Storage Volume – Historical and Range of CCAM Climate Model Results with Specified Trigger Levels (for 8 Common Climate Models) (Rainfall Not Adjusted).

I.3 Comparison of Generation Methods

I.3.1 GCM and CCAM

Table 7.31 Description of Relevant Generation Methods.

Generation Method	Gridsize	Description
GCM	Ranging from 100 to 400km	Global circulation models developed by various research institutes around the world
CCAM	~20km	Original dynamically downscaled models using the Conformal-Cubic Atmospheric Model (CCAM) – downscaled to 20km
CCAM PPE1	~ 8km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 8km
CCAM PPE1	~20km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 20km

Table 7.32 Average Recurrence Interval of Years Where Combined Storage (Wivenhoe and Somerset Dams) Falls below Specified Trigger Levels (Level of Service) – Comparison of Generation Methods under CSIRO Mark 3.0.

Method Of Climate Data Generation (CSIRO Mark 3.0)	Trigger Level in Combined Storage			
	Wivenhoe and Somerset Dams			
	Dead Storage Volume	25%	50%	75%
	8,886ML	386,000ML	773,000ML	1,159,000ML
Historical	>111.0	111.0	12.3	2.1
CCAM	37.0	3.8	2.1	1.4
CCAM - Rainfall Not Adjusted	>111.0	6.2	2.2	1.4
GCM	>111.0	13.9	3.2	1.5
GCM - Rainfall Not Adjusted	>111.0	7.9	2.4	1.4

Table 7.33 Average Recurrence Interval of Years Where Combined Storage (Wivenhoe and Somerset Dams) Falls below Specified Trigger Levels (Level of Service) – Comparison of Generation Methods under CSIRO Mark 3.5.

Method Of Climate Data Generation (CSIRO Mark 3.5)	Trigger Level in Combined Storage			
	Wivenhoe and Somerset Dams			
	Dead Storage Volume	25%	50%	75%
	8,886ML	386,000ML	773,000ML	1,159,000ML
Historical	>111.0	111.0	12.3	2.1
CCAM	15.9	3.0	2.0	1.4
CCAM - Rainfall Not Adjusted	111.0	4.4	2.1	1.4
GCM	>111.0	6.9	2.3	1.4
GCM - Rainfall Not Adjusted	>111.0	18.5	3.0	1.6

Table 7.34 Average Recurrence Interval of Years Where Combined Storage (Wivenhoe and Somerset Dams) Falls below Specified Trigger Levels (Level of Service) – Comparison of Generation Methods under GFDL CM21.

Method Of Climate Data Generation (GFDL CM21)	Trigger Level in Combined Storage Wivenhoe and Somerset Dams			
	Dead Storage Volume	25%	50%	75%
	8,886ML	386,000ML	773,000ML	1,159,000ML
Historical	>111.0	111.0	12.3	2.1
CCAM	6.2	2.5	1.8	1.3
CCAM - Rainfall Not Adjusted	111.0	4.4	2.1	1.4
GCM	4.6	2.1	1.6	1.3
GCM - Rainfall Not Adjusted	>111.0	15.9	2.9	1.5

Table 7.35 Average Recurrence Interval of Years Where Combined Storage (Wivenhoe and Somerset Dams) Falls below Specified Trigger Levels (Level of Service) – Comparison of Generation Methods under MIROC 3.2 medres.

Method Of Climate Data Generation (MIROC 3.2 medres)	Trigger Level in Combined Storage Wivenhoe and Somerset Dams			
	Dead Storage Volume	25%	50%	75%
	8,886ML	386,000ML	773,000ML	1,159,000ML
Historical	>111.0	111.0	12.3	2.1
CCAM	>111.0	27.8	6.9	1.7
CCAM - Rainfall Not Adjusted	>111.0	6.9	2.4	1.4
GCM	>111.0	>111.0	37.0	3.6
GCM - Rainfall Not Adjusted	>111.0	37.0	6.5	1.8

Table 7.36 Average Recurrence Interval of Years Where Combined Storage (Wivenhoe and Somerset Dams) Falls below Specified Trigger Levels (Level of Service) – Comparison of Generation Methods under MPI ECHAM5.

Method Of Climate Data Generation (MPI ECHAM5)	Trigger Level in Combined Storage Wivenhoe and Somerset Dams			
	Dead Storage Volume	25%	50%	75%
	8,886ML	386,000ML	773,000ML	1,159,000ML
Historical	>111.0	111.0	12.3	2.1
CCAM	13.9	3.0	1.9	1.4
CCAM - Rainfall Not Adjusted	>111.0	6.5	2.3	1.4
GCM	37.0	4.4	2.2	1.4
GCM - Rainfall Not Adjusted	>111.0	18.5	3.4	1.6

Table 7.37 Average Recurrence Interval of Years Where Combined Storage (Wivenhoe and Somerset Dams) Falls below Specified Trigger Levels (Level of Service) – Comparison of Generation Methods under NCAR CCSM3.

Method Of Climate Data Generation (NCAR CCSM3)	Trigger Level in Combined Storage Wivenhoe and Somerset Dams			
	Dead Storage Volume	25%	50%	75%
	8,886ML	386,000ML	773,000ML	1,159,000ML
Historical	>111.0	111.0	12.3	2.1
CCAM	55.5	3.8	2.1	1.4
CCAM - Rainfall Not Adjusted	>111.0	7.9	2.5	1.5
GCM	>111.0	27.8	6.9	1.8
GCM - Rainfall Not Adjusted	>111.0	27.8	4.4	1.7

Table 7.38 Average Recurrence Interval of Years Where Combined Storage (Wivenhoe and Somerset Dams) Falls below Specified Trigger Levels (Level of Service) – Comparison of Generation Methods under UKMO HadCM3.

Method Of Climate Data Generation (UKMO HadCM3)	Trigger Level in Combined Storage Wivenhoe and Somerset Dams			
	Dead Storage Volume	25%	50%	75%
	8,886ML	386,000ML	773,000ML	1,159,000ML
Historical	>111.0	111.0	12.3	2.1
CCAM	>111.0	12.3	2.8	1.5
CCAM - Rainfall Not Adjusted	>111.0	9.3	2.7	1.5
GCM	55.5	5.8	2.2	1.4
GCM - Rainfall Not Adjusted	>111.0	18.5	3.5	1.6

Table 7.39 Average Recurrence Interval of Years Where Combined Storage (Wivenhoe and Somerset Dams) Falls below Specified Trigger Levels (Level of Service) – Comparison of Generation Methods under UKMO HadGEM1.

Method Of Climate Data Generation (UKMO HadGEM1)	Trigger Level in Combined Storage Wivenhoe and Somerset Dams			
	Dead Storage Volume	25%	50%	75%
	8,886ML	386,000ML	773,000ML	1,159,000ML
Historical	>111.0	111.0	12.3	2.1
CCAM	12.3	3.1	1.9	1.3
CCAM - Rainfall Not Adjusted	>111.0	5.8	2.2	1.4
GCM	22.2	3.6	2.0	1.4
GCM - Rainfall Not Adjusted	>111.0	27.8	4.3	1.7

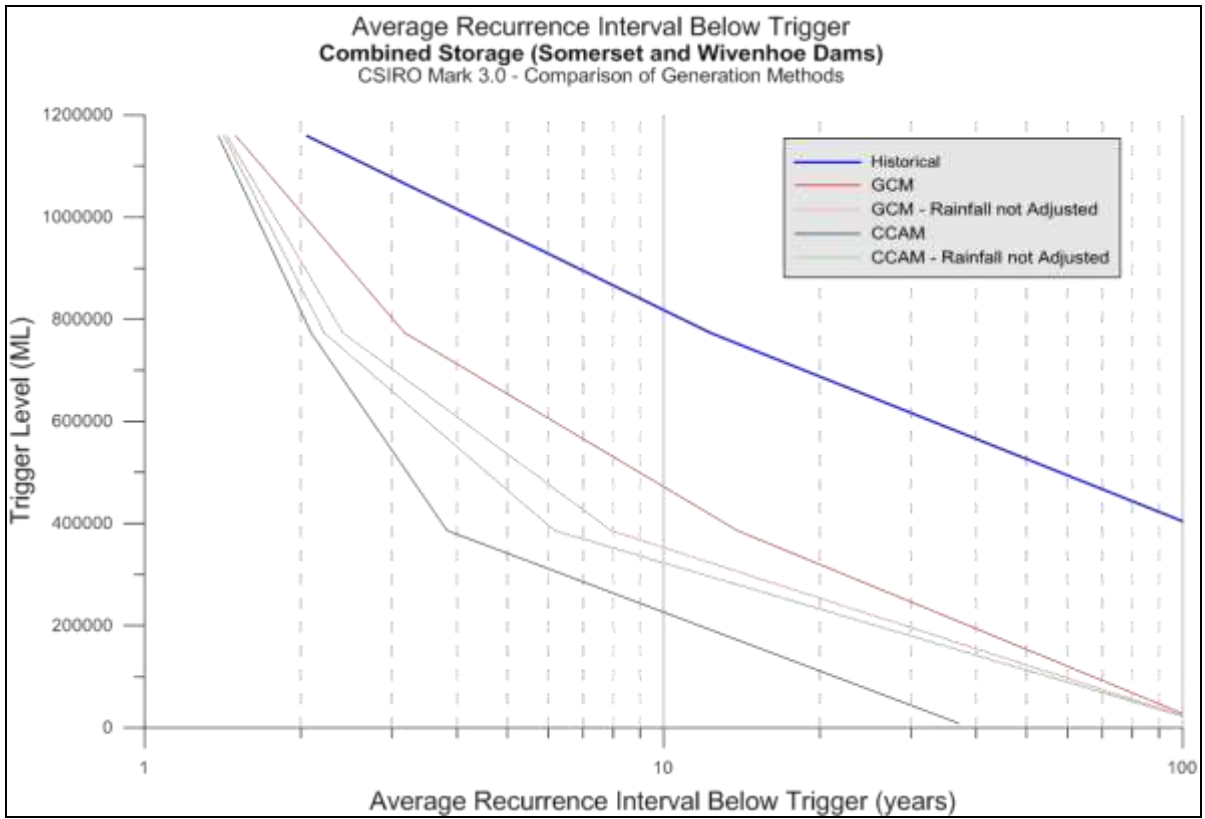


Figure I.13 Average Recurrence Interval Below Specified Trigger Levels - Combined Wivenhoe and Somerset Dams – Comparison of Generation Methods under CSIRO Mark 3.0 (GCM and CCAM).

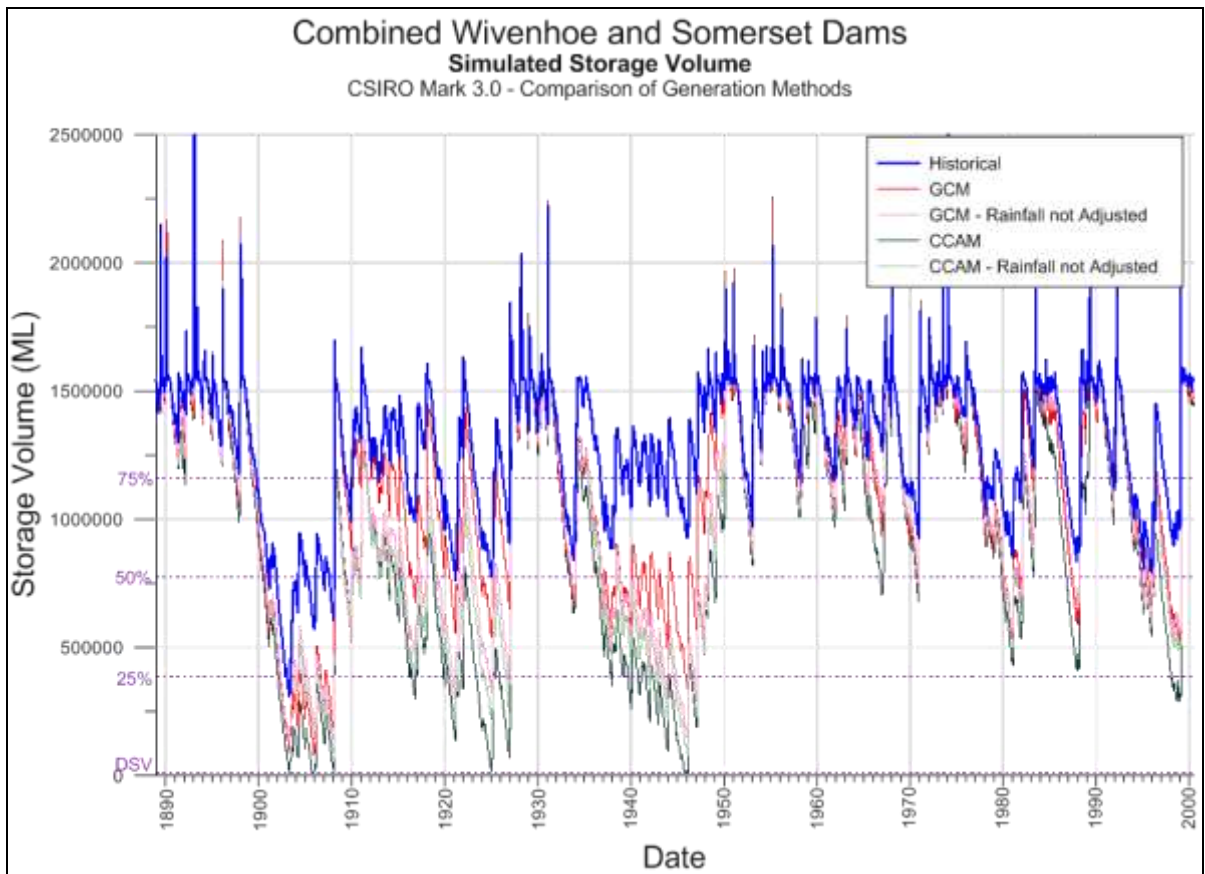


Figure I.14 Combined Wivenhoe and Somerset Dam Storage Volume with Specified Trigger Levels – Comparison of Generation Methods under CSIRO Mark 3.0 (GCM and CCAM).

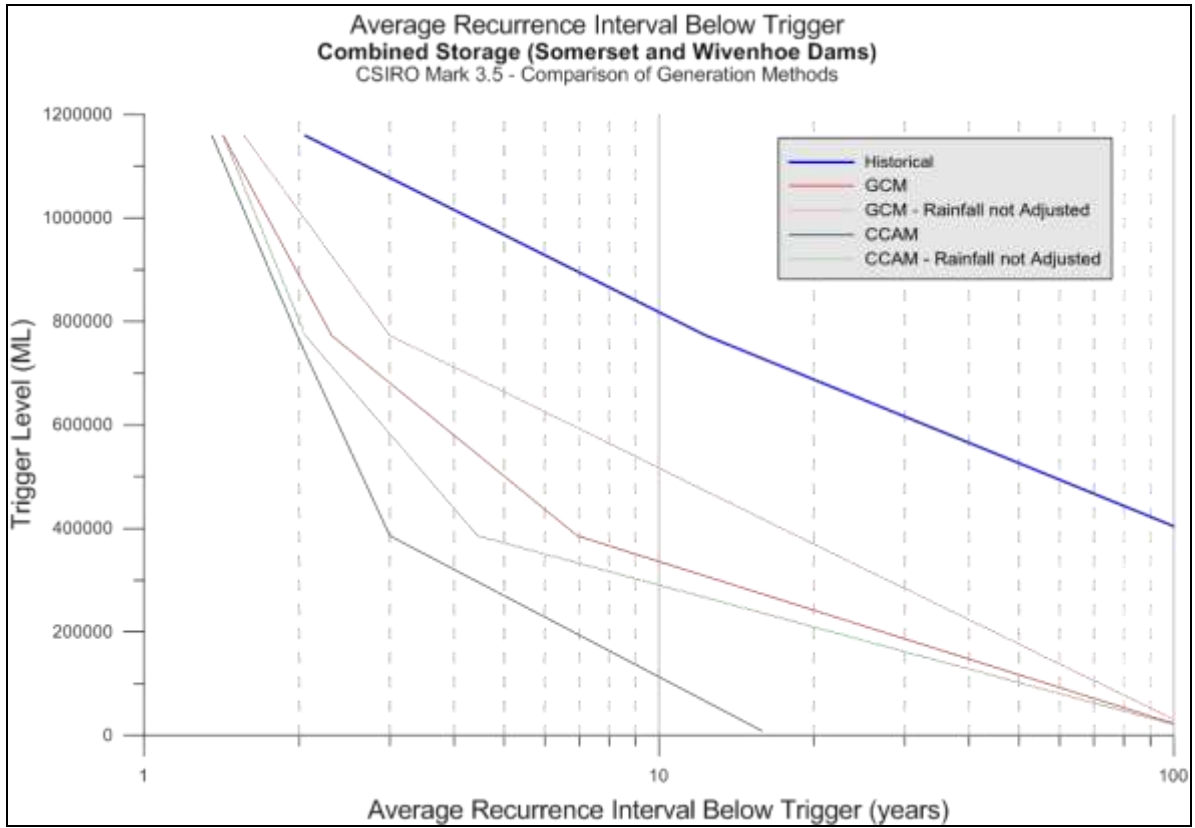


Figure I.15 Average Recurrence Interval Below Specified Trigger Levels - Combined Wivenhoe and Somerset Dams – Comparison of Generation Methods under CSIRO Mark 3.5 (GCM and CCAM).

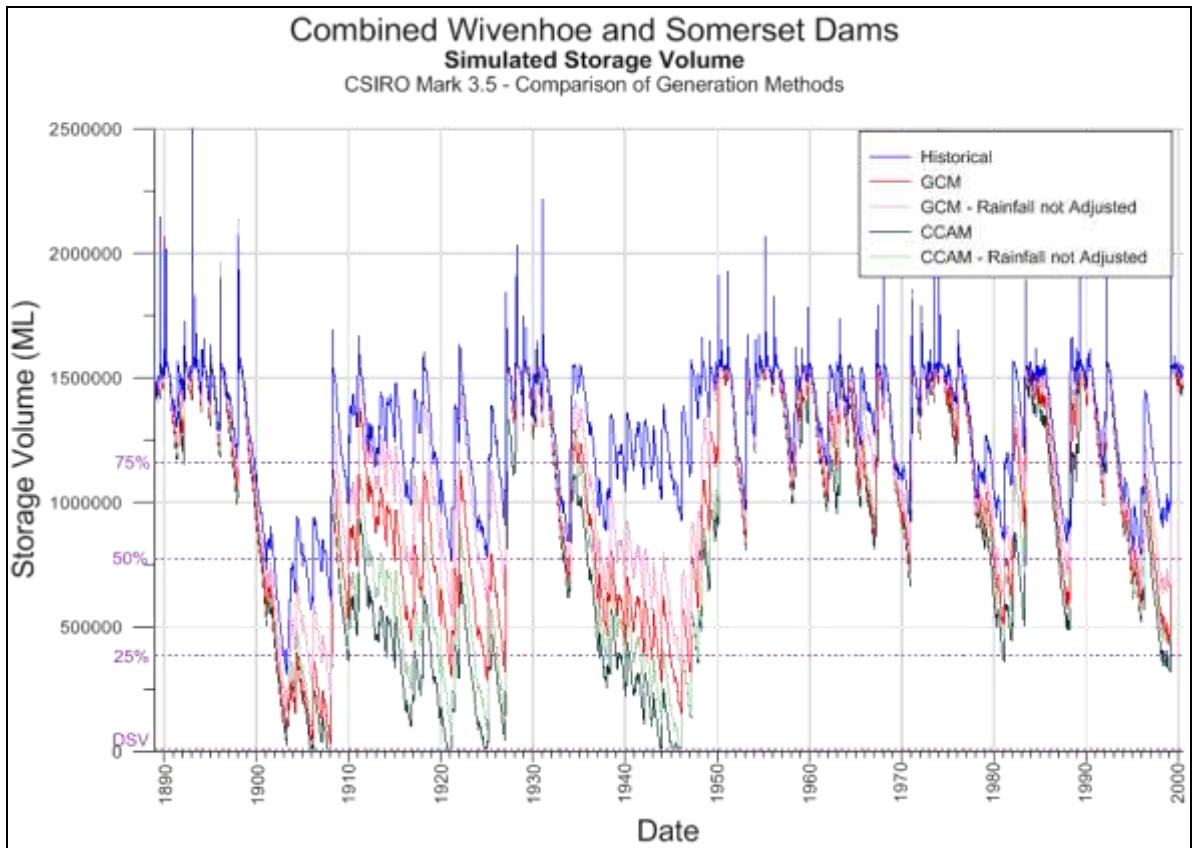


Figure I.16 Combined Wivenhoe and Somerset Dam Storage Volume with Specified Trigger Levels – Comparison of Generation Methods under CSIRO Mark 3.5 (GCM and CCAM).

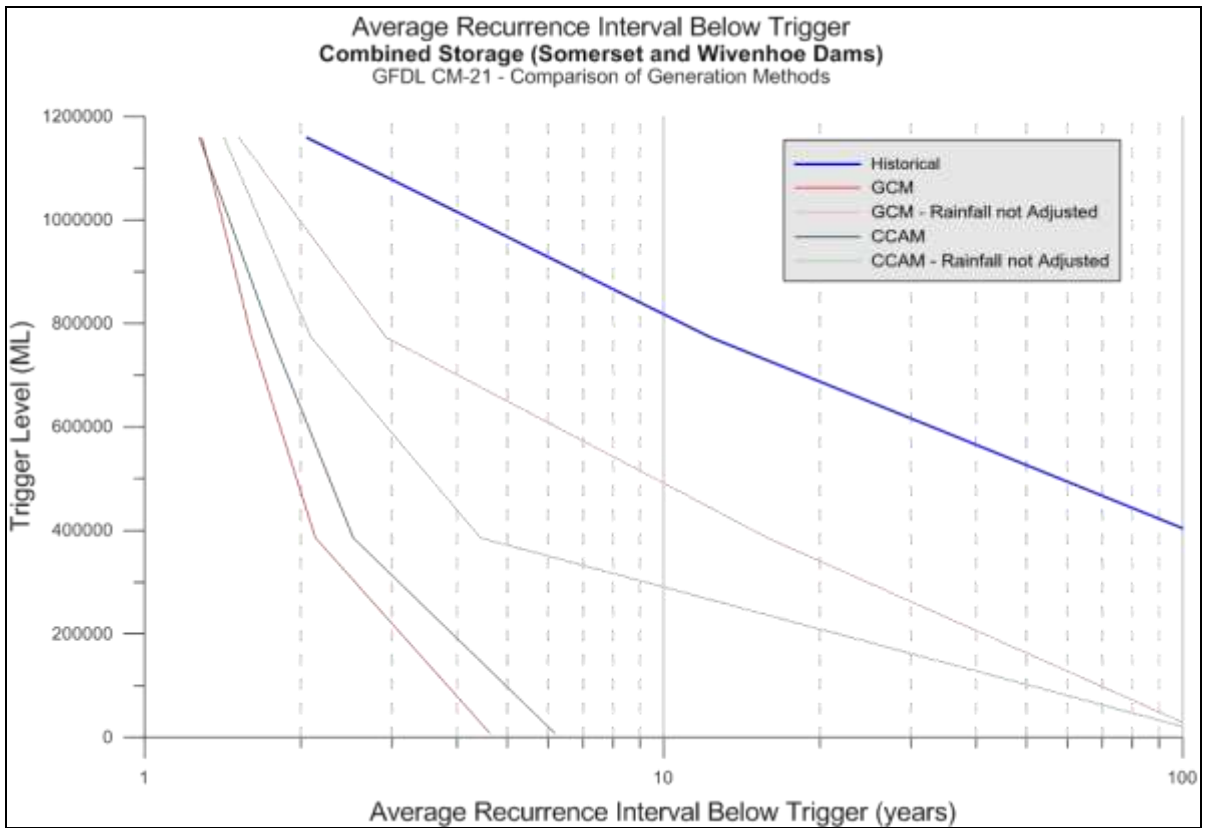


Figure I.17 Average Recurrence Interval Below Specified Trigger Levels - Combined Wivenhoe and Somerset Dams – Comparison of Generation Methods under GFDL CM21 (GCM and CCAM).

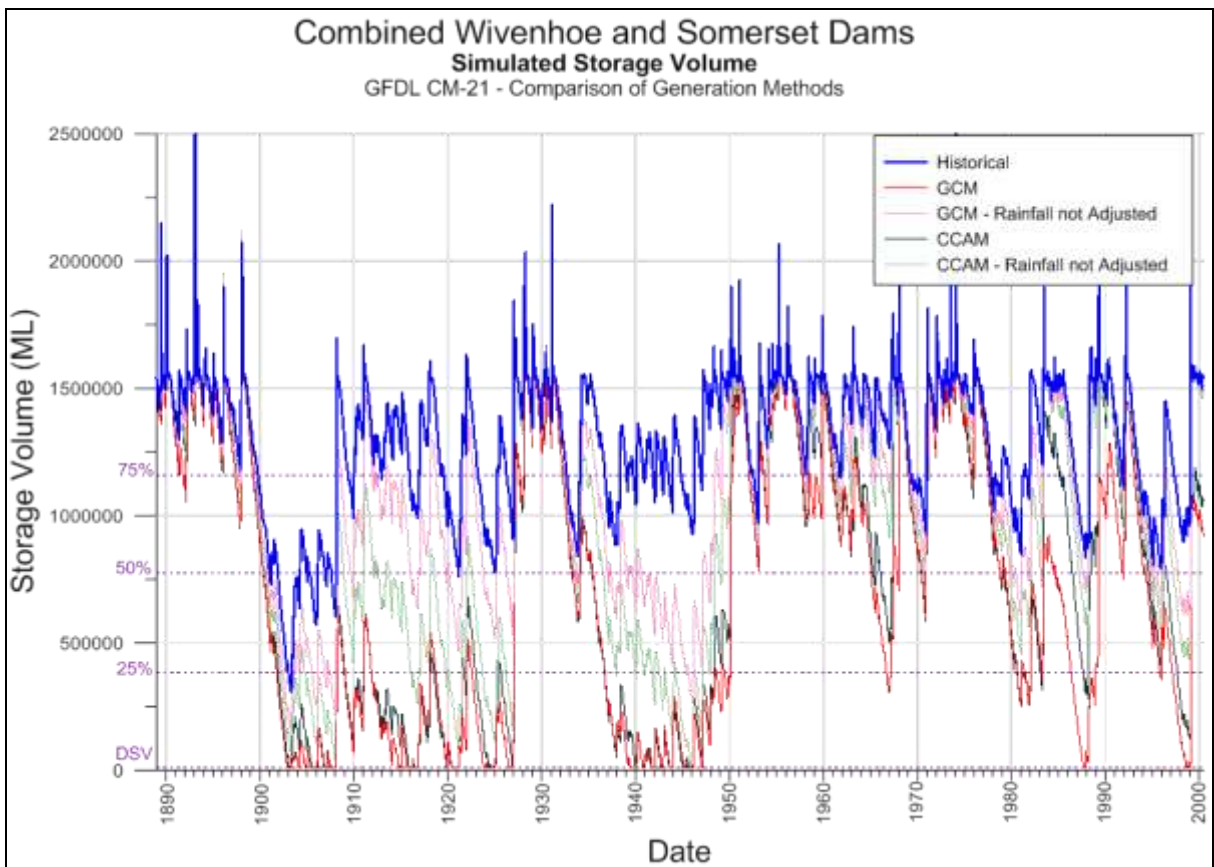


Figure I.18 Combined Wivenhoe and Somerset Dam Storage Volume with Specified Trigger Levels – Comparison of Generation Methods under GFDL CM21 (GCM and CCAM).

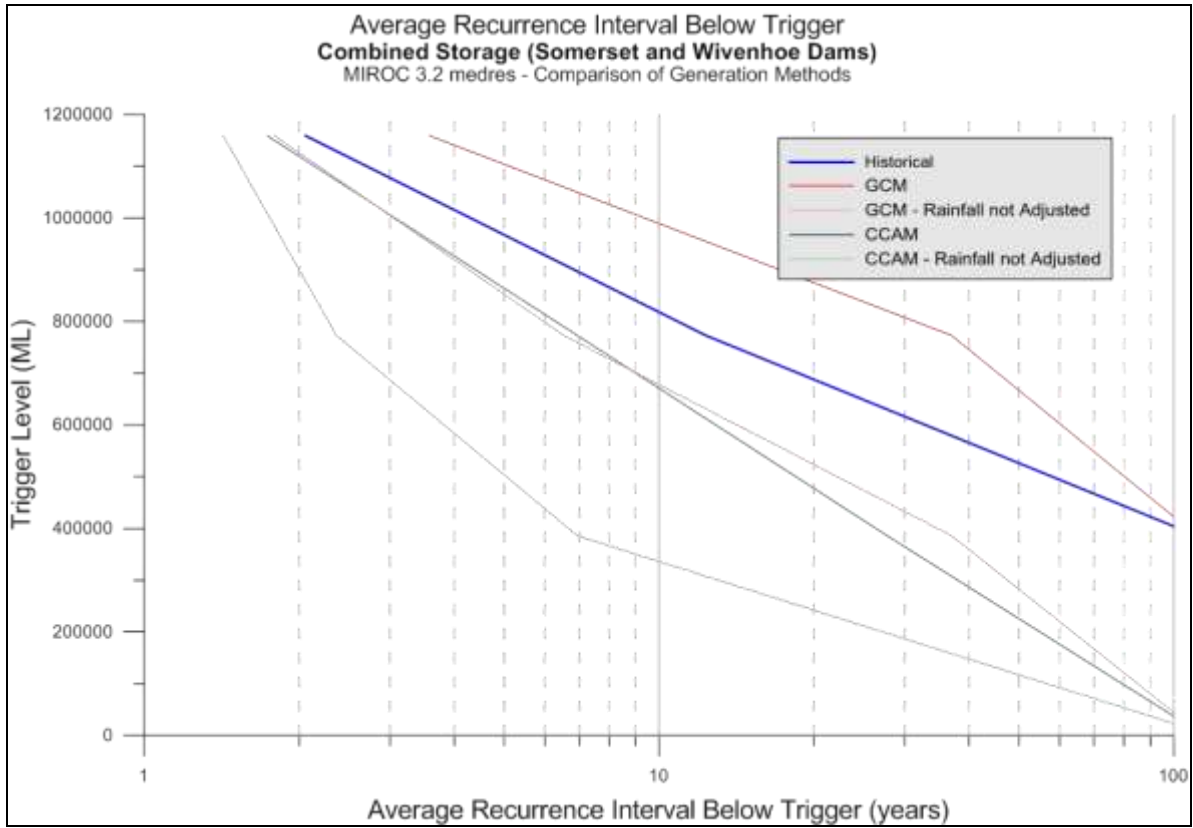


Figure I.19 Average Recurrence Interval Below Specified Trigger Levels - Combined Wivenhoe and Somerset Dams – Comparison of Generation Methods under MIROC 3.2 medres (GCM and CCAM).

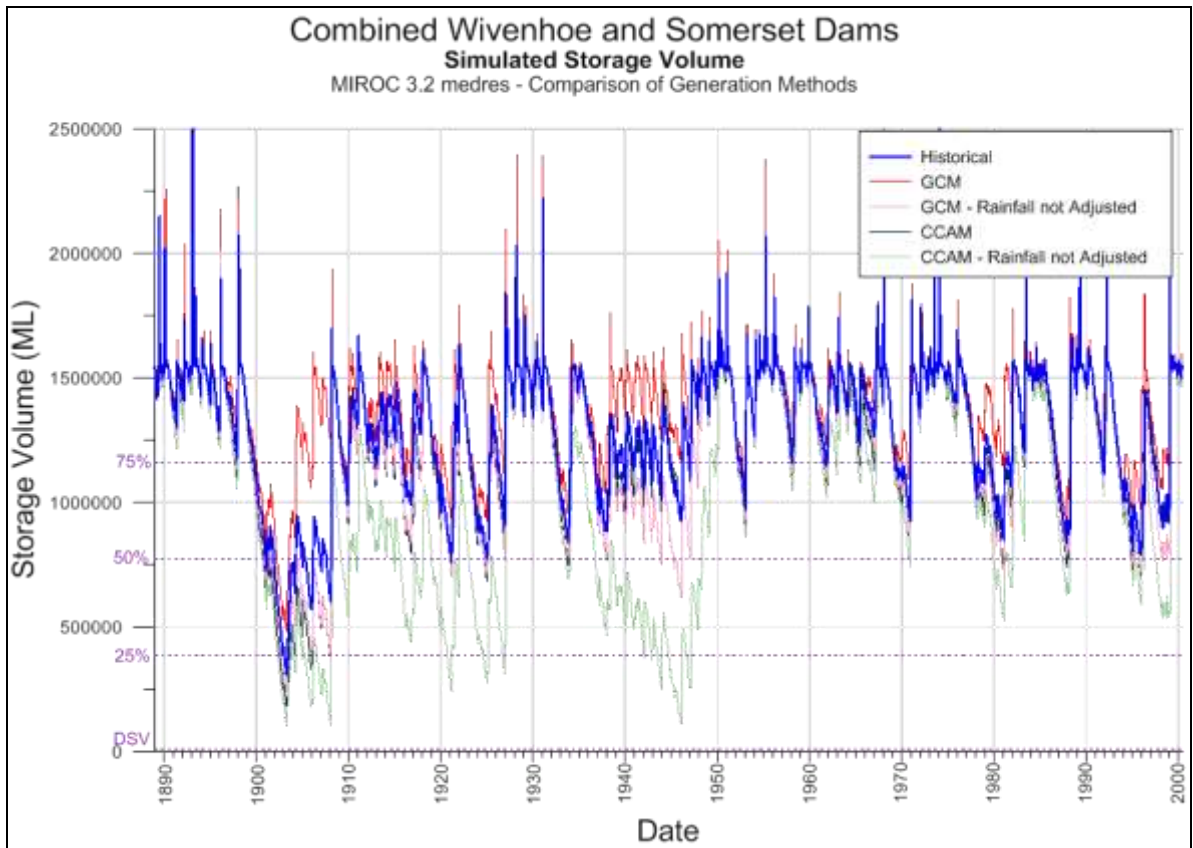


Figure I.20 Combined Wivenhoe and Somerset Dam Storage Volume with Specified Trigger Levels – Comparison of Generation Methods under MIROC 3.2 medres (GCM and CCAM).

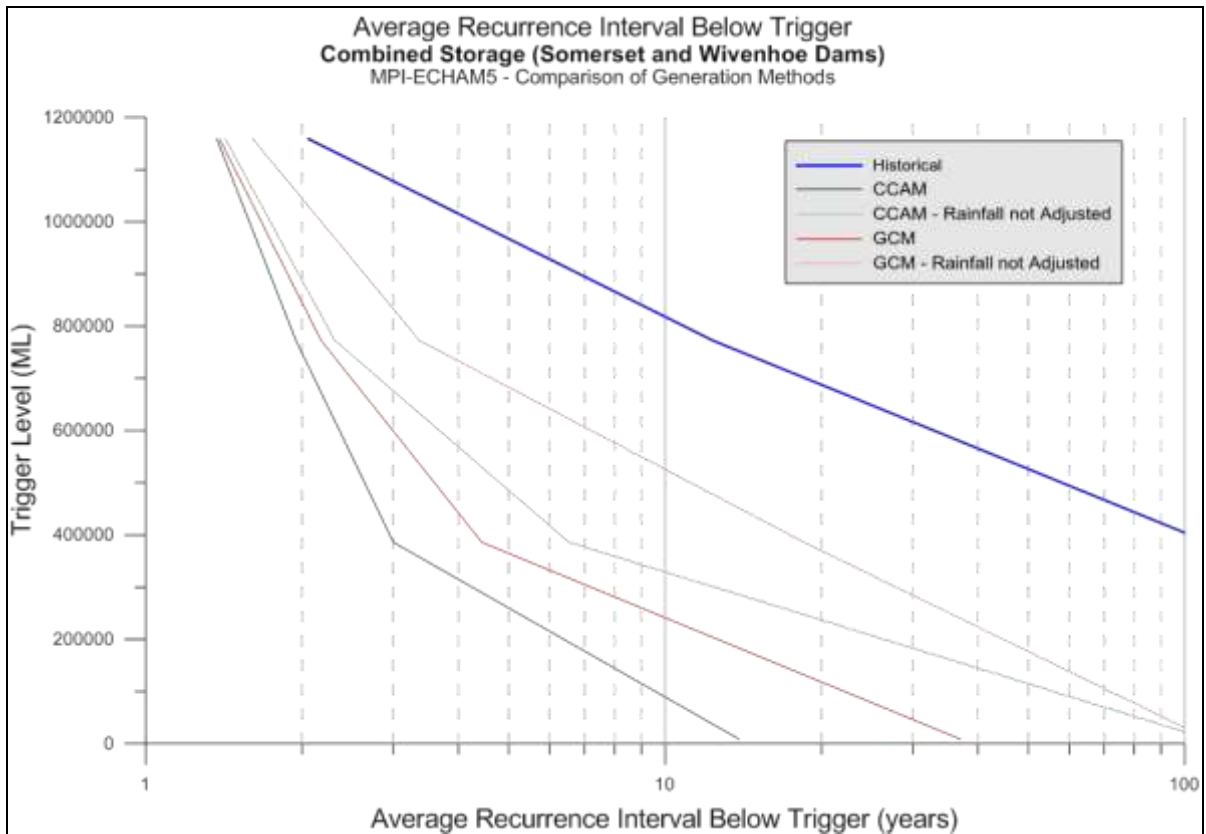


Figure I.21 Average Recurrence Interval Below Specified Trigger Levels - Combined Wivenhoe and Somerset Dams – Comparison of Generation Methods under MPI ECHAM5 (GCM and CCAM).

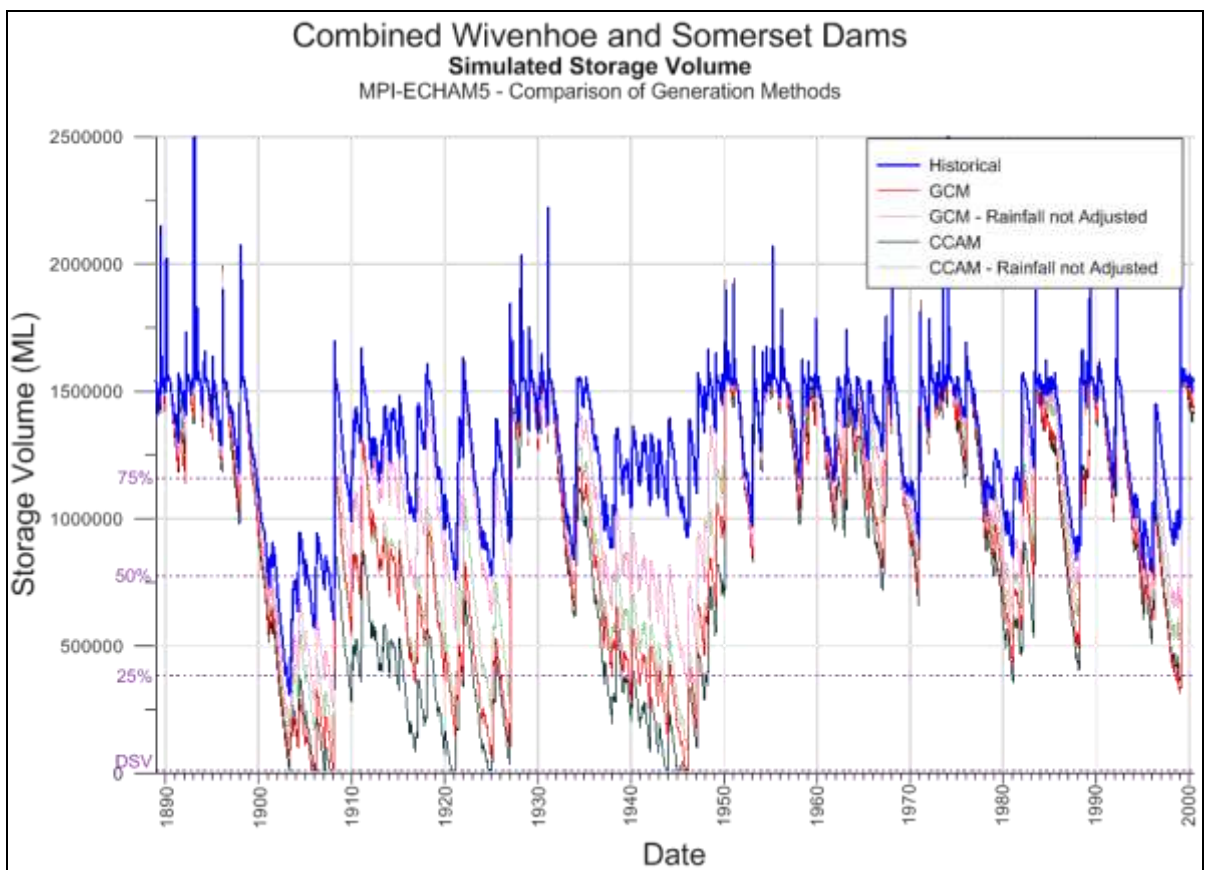


Figure I.22 Combined Wivenhoe and Somerset Dam Storage Volume with Specified Trigger Levels – Comparison of Generation Methods under MPI ECHAM5 (GCM and CCAM).

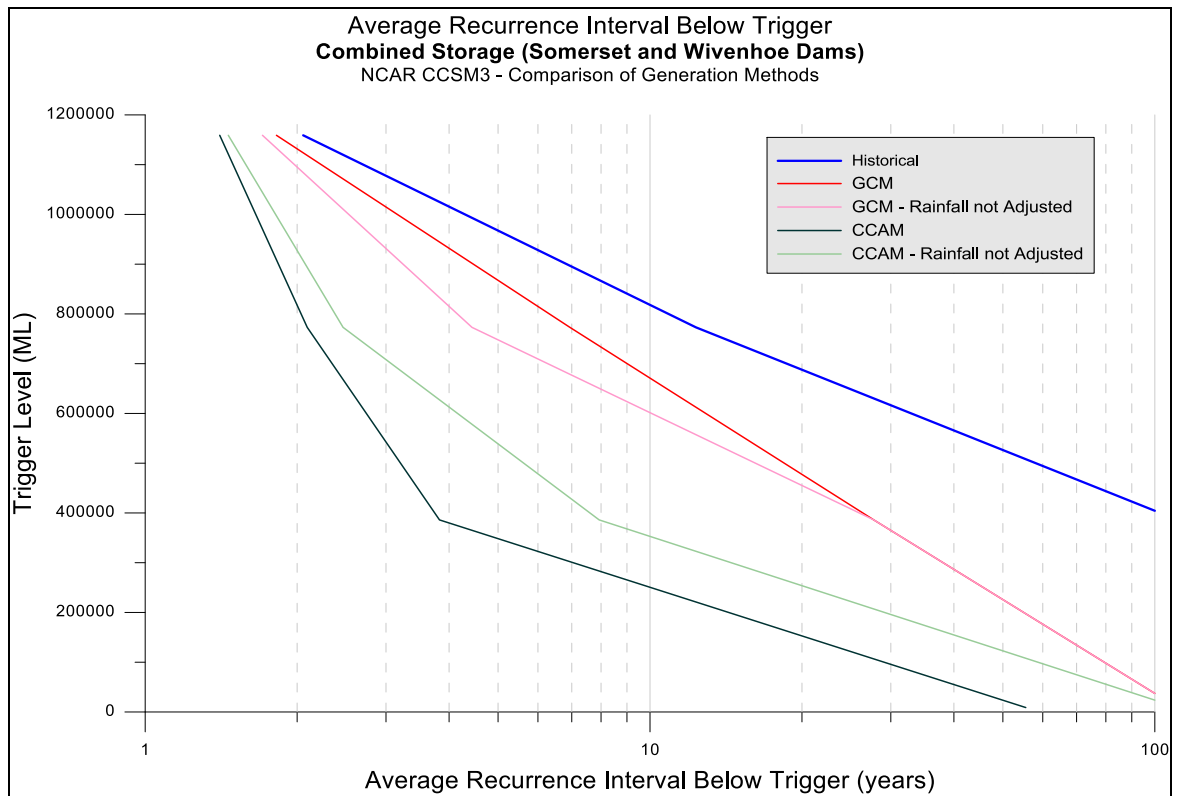


Figure I.23 Average Recurrence Interval Below Specified Trigger Levels - Combined Wivenhoe and Somerset Dams – Comparison of Generation Methods under NCAR CCSM3 (GCM and CCAM).

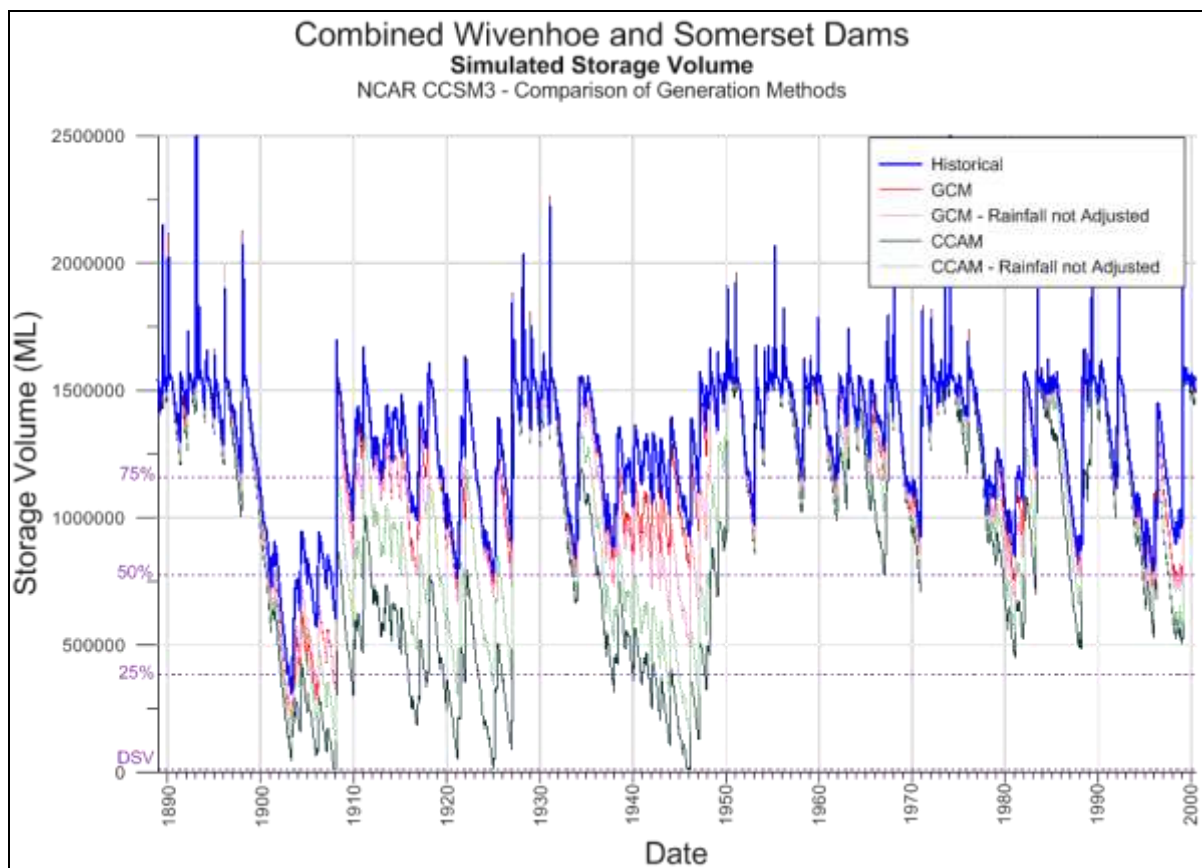


Figure I.24 Combined Wivenhoe and Somerset Dam Storage Volume with Specified Trigger Levels – Comparison of Generation Methods under NCAR CCSM3 (GCM and CCAM).

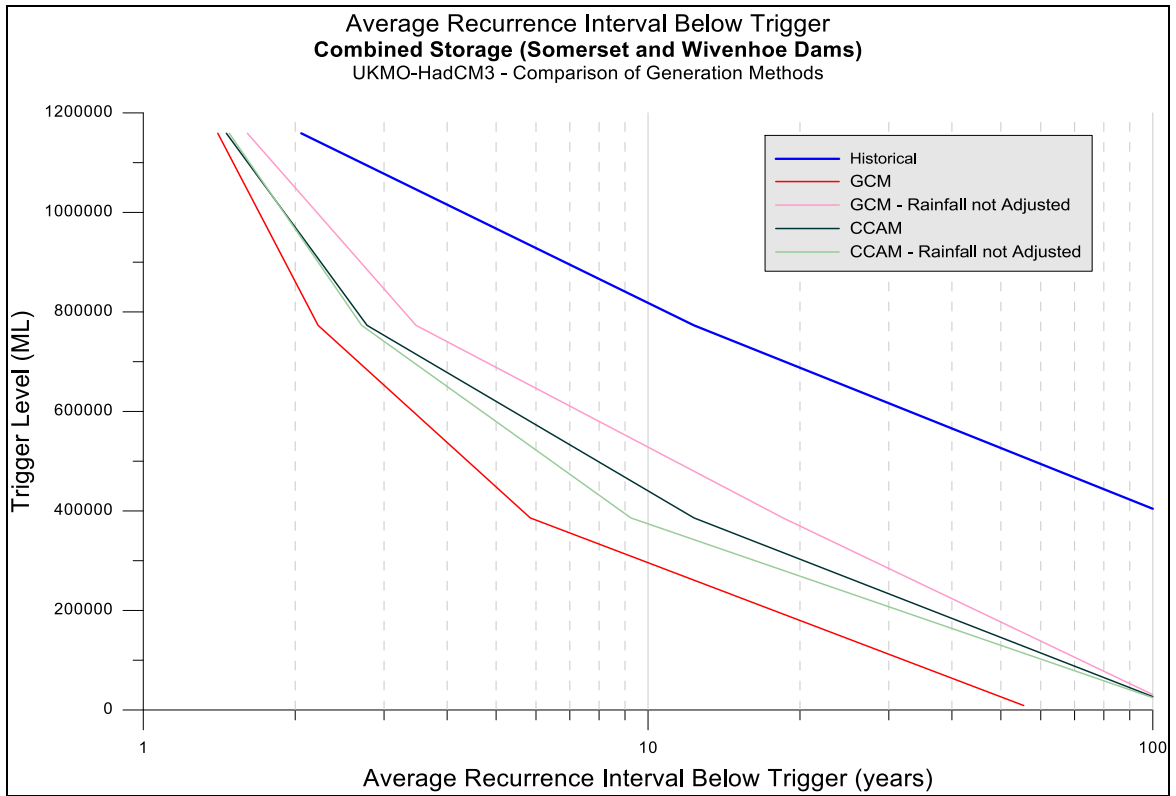


Figure I.25 Average Recurrence Interval Below Specified Trigger Levels - Combined Wivenhoe and Somerset Dams – Comparison of Generation Methods under UKMO HadCM3 (GCM and CCAM).

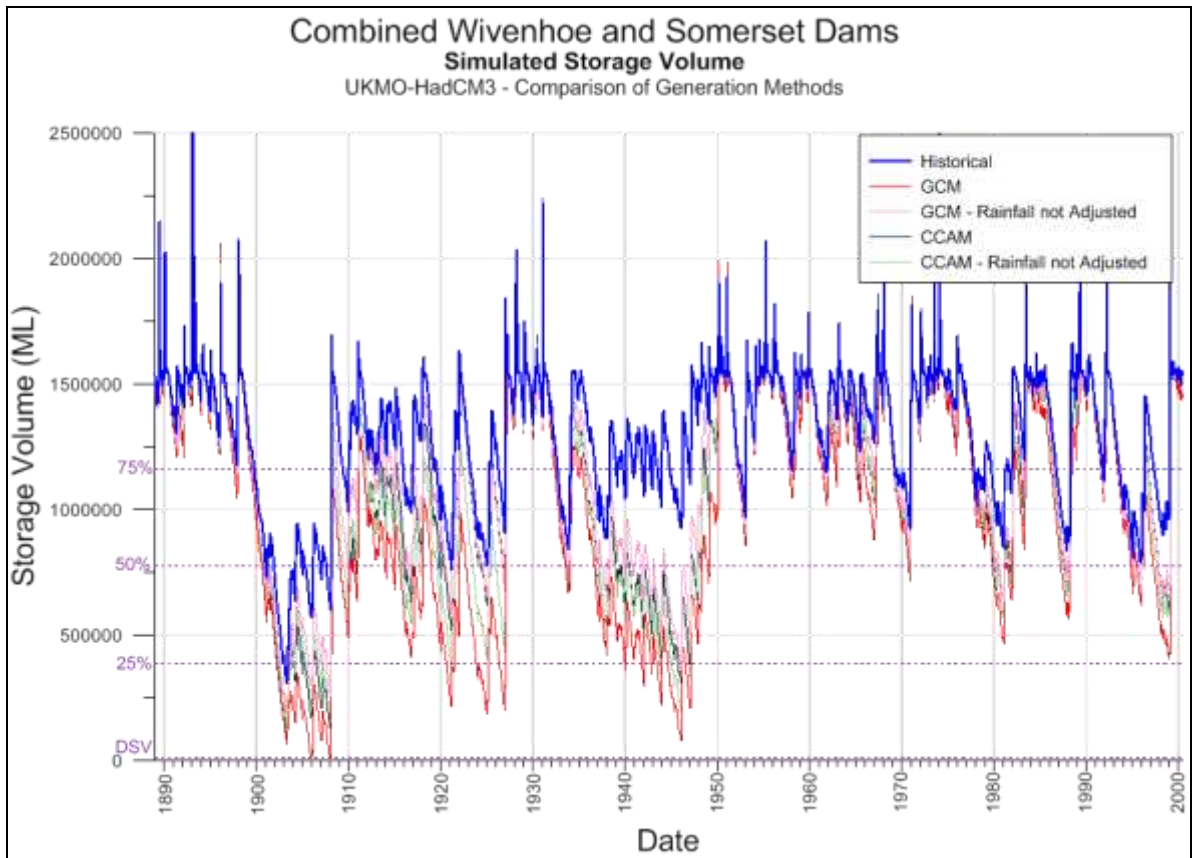


Figure I.26 Combined Wivenhoe and Somerset Dam Storage Volume with Specified Trigger Levels – Comparison of Generation Methods under UKMO HadCM3 (GCM and CCAM).

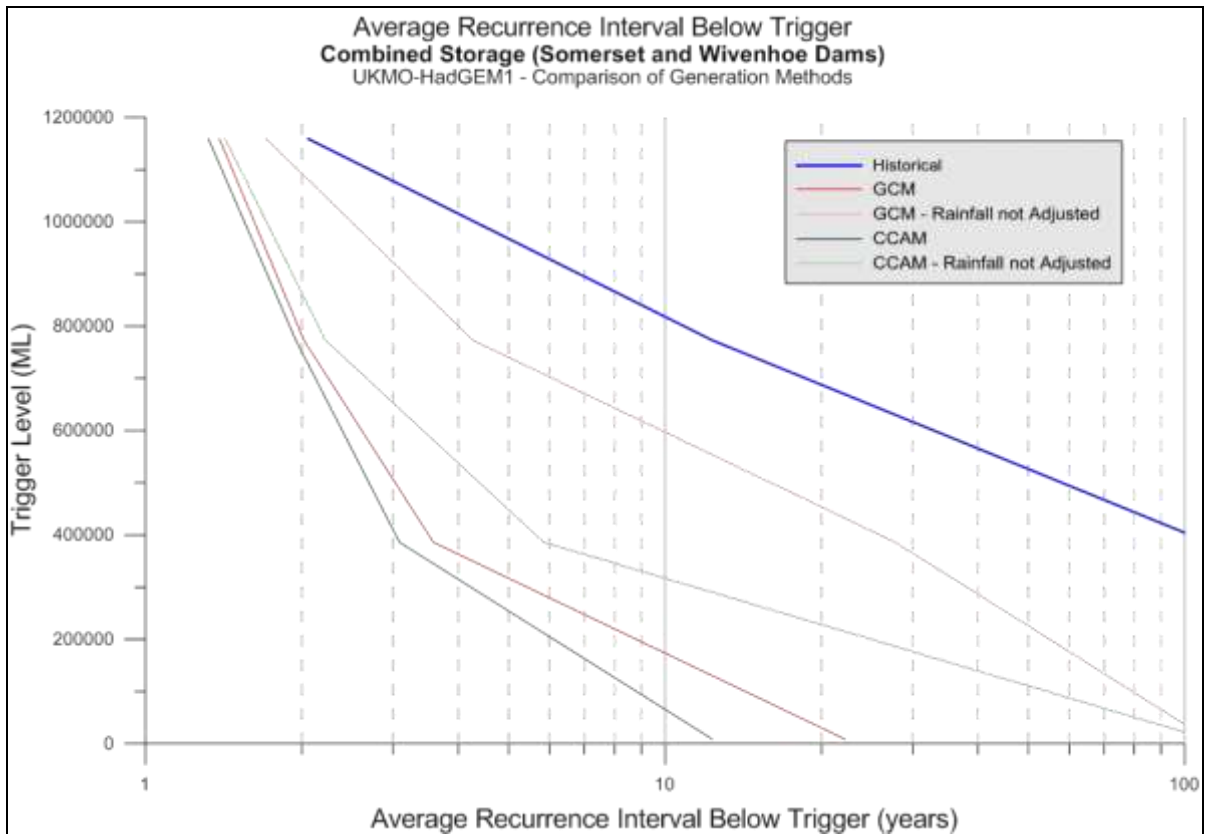


Figure I.27 Average Recurrence Interval Below Specified Trigger Levels - Combined Wivenhoe and Somerset Dams – Comparison of Generation Methods under UKMO HadGEM1 (GCM and CCAM).

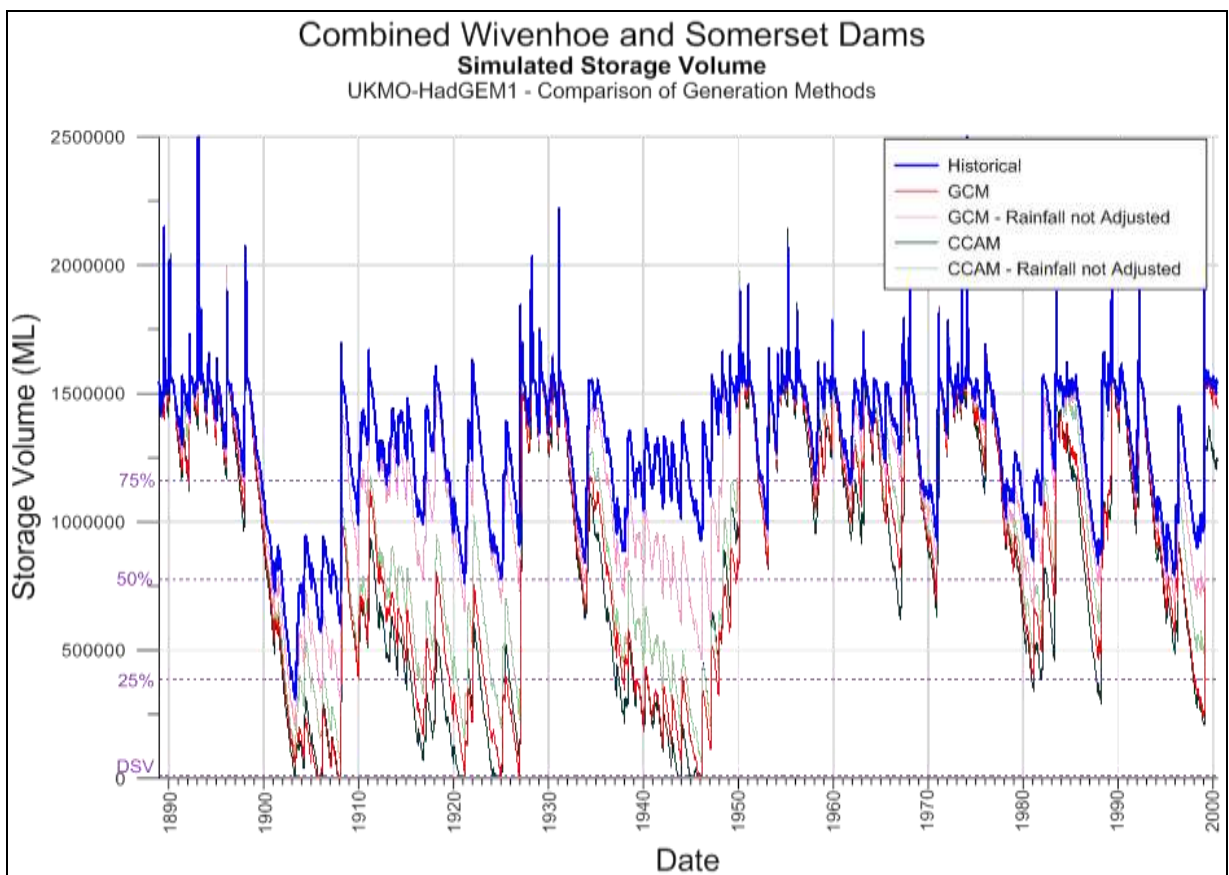


Figure I.28 Combined Wivenhoe and Somerset Dam Storage Volume with Specified Trigger Levels – Comparison of Generation Methods under UKMO HadGEM1 (GCM and CCAM).

I.3.2 GCM, CCAM and CCAM PPE1

Table 7.40 Description of Relevant Generation Methods.

Generation Method	Gridsize	Description
GCM	Ranging from 100 to 400km	Global circulation models developed by various research institutes around the world
CCAM	~20km	Original dynamically downscaled models using the Conformal-Cubic Atmospheric Model (CCAM) – downscaled to 20km
CCAM PPE1	~ 8km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 8km
CCAM PPE1	~20km	Conformal-Cubic Atmospheric Model (CCAM) downscaling with changes to uncertainty physical parameters (Perturbed Physics Experiment 1 (PPE1)) – downscaled to 20km

Table 7.41 Average Recurrence Interval of Years Where Combined Storage (Wivenhoe and Somerset Dams) Falls below Specified Trigger Levels (Level of Service) – Comparison of Generation Methods under GFDL CM21.

Method Of Climate Data Generation (GFDL CM21)	Trigger Level in Combined Storage Wivenhoe and Somerset Dams			
	Dead Storage Volume	25%	50%	75%
	8,886ML	386,000ML	773,000ML	1,159,000ML
Historical	>111.0	111.0	12.3	2.1
CCAM - 20km	6.2	2.5	1.8	1.3
CCAM - 20km - Rainfall Not Adjusted	111.0	4.4	2.1	1.4
CCAM PPE1 - 8km	2.7	2.6	1.4	1.1
CCAM PPE1 - 8km - Rainfall Not Adjusted	6.5	2.5	1.7	1.2
CCAM PPE1 - 20km	7.4	2.8	1.8	1.2
CCAM PPE1 - 20km - Rainfall Not Adjusted	15.9	3.1	2.0	1.4
GCM	4.6	2.1	1.6	1.3
GCM - Rainfall Not Adjusted	>111.0	15.9	2.9	1.5

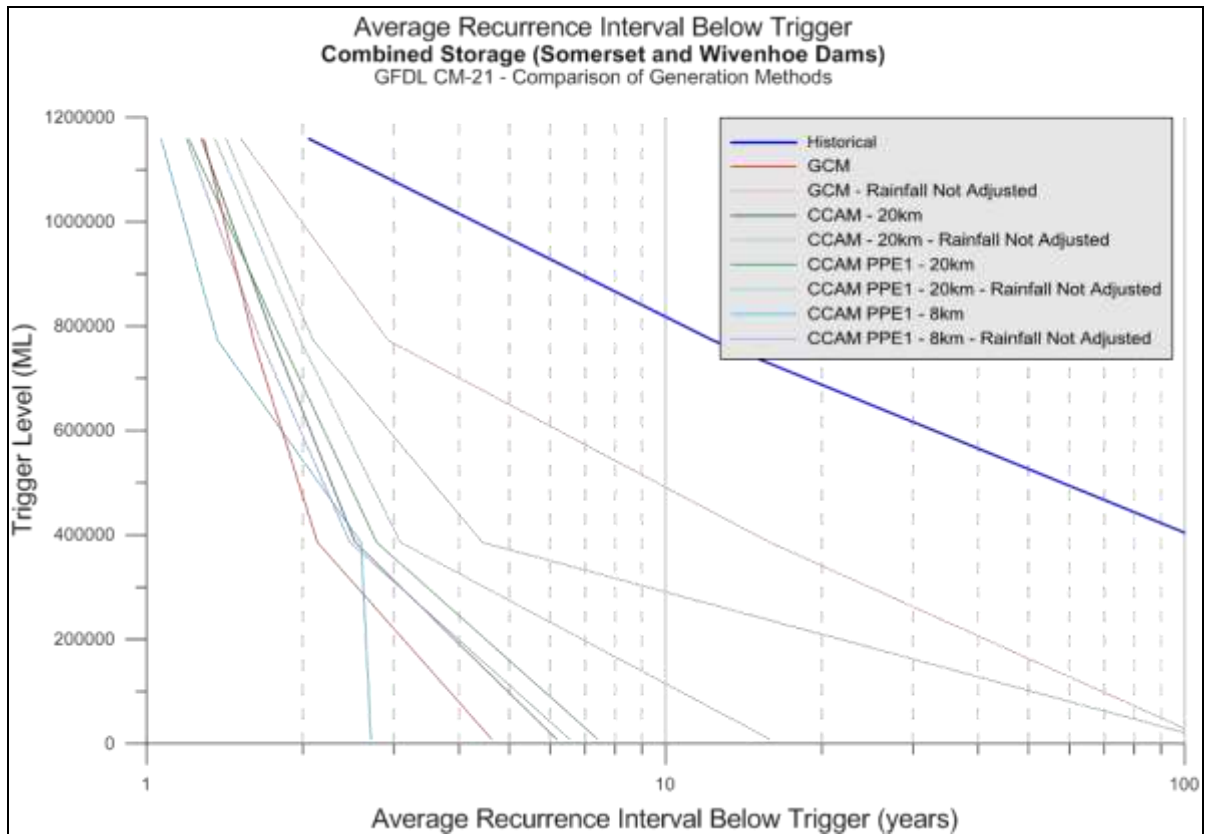


Figure I.29 Average Recurrence Interval Below Specified Trigger Levels - Combined Wivenhoe and Somerset Dams – Comparison of Generation Methods under GFDL CM21 (GCM, CCAM and CCAM PPE1).

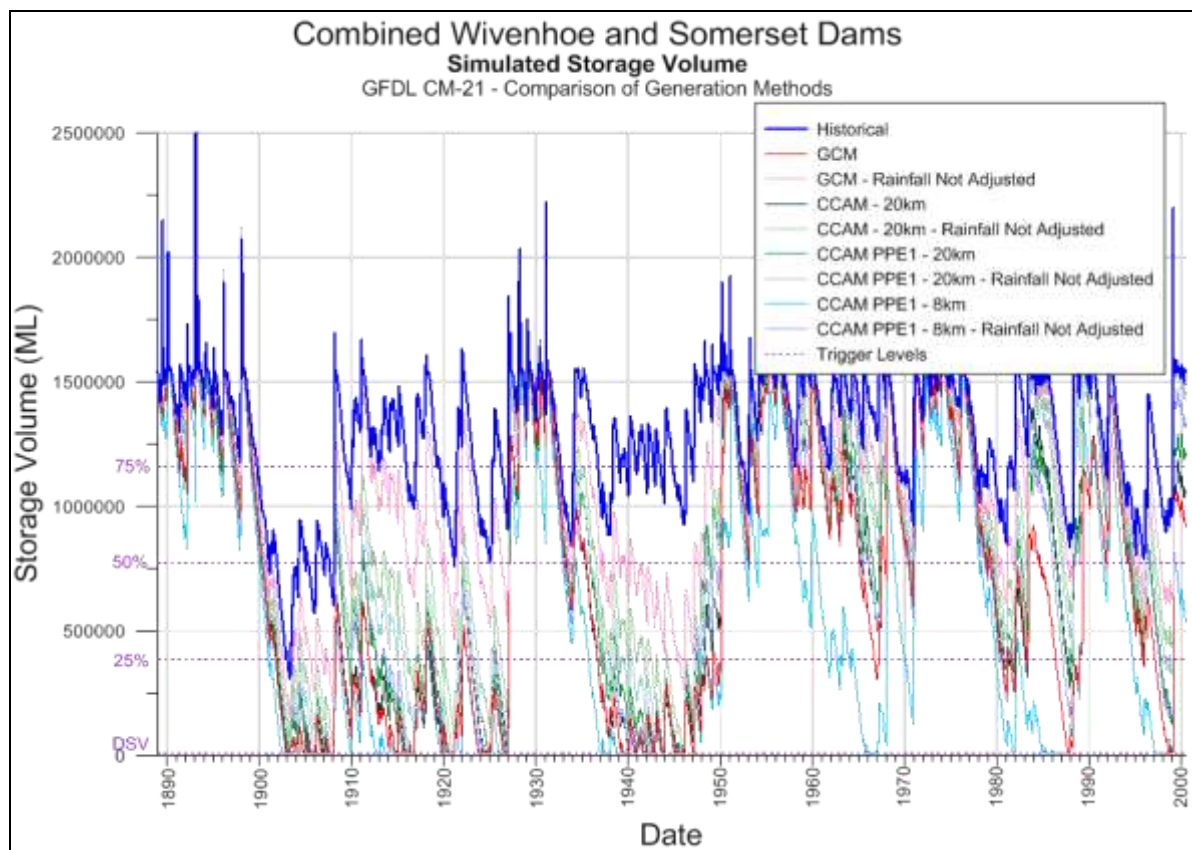


Figure I.30 Combined Wivenhoe and Somerset Dam Storage Volume with Specified Trigger Levels – Comparison of Generation Methods under GFDL CM21 (GCM, CCAM and CCAM PPE1).

ABBREVIATIONS

Abbreviation	Definition
AHD	Australian Height Datum
AMTD	Adopted Middle Thread Distance
APFD	Annual Proportional Flow Deviation
BoM	Bureau of Meteorology
CA	Catchment area
CINRS	Climate Impacts and Natural Resource Systems (a group within NRW)
Ck	Creek
cumecs	Cubic metres per second
DLWC	Department of Land and Water Conservation (NSW)
DMM	Data Modification Module
DPI	Department of Primary Industries
D/S	Downstream
DS	Dead storage
EFO	Environmental Flow Objective
FSA	Full supply area
FSL	Full supply level
FSV	Full supply volume
GL	Gigalitres
GS	Gauging Station
ha	Hectare
HNFY	Historical no-failure yield
HW	Headwater
IQQM	Integrated Quantity-Quality Model
IROL	Interim Resource Operations Licence
IRM	Integrated Resource Management
IWA	Interim Water Allocation
km	Kilometres
km ²	Square kilometres
Lat	Latitude
Long	Longitude
m	Metres
MAD	Mean Annual Diversion
MAF	Mean Annual Flow
MAR	Mean Annual Rainfall
MARO	Mean Annual Runoff
Max	Maximum
Min	Minimum
ML	Megalitres
Mm	Millimetres
mth	Month
m ³ /s	Cubic metres per second
N/A	Not applicable

Abbreviation	Definition
NRM	Department of Natural Resources and Mines
NRMW	Department of Natural Resources, Mines and Water
NRW	Department of Natural Resources and Water
PAWC	Plant Available Water Capacity
PET	Potential evapotranspiration
ROL	Resource Operations Licence
ROP	Resource Operations Plan
Qld	Queensland
SEQRWSS	South East Queensland Regional Water Supply Strategy
SID	Storage Inflow Derivation
SILO	BoM's Internet website that provides meteorological and agricultural data
TWS	Town water supply
U/S	Upstream
WASO	Water Allocation Security Objectives
WB	Water Board
WERD	Water Entitlements Registration Database
WRP	Water Resource Plan
WSI	Water Sharing Index
WSS	Water Supply Scheme
AEP	Annual exceedance probability
AR4	IPCC Fourth Assessment Report
ARI	Average recurrence interval
CC	Climate Change
CCAM	Cubic Conformal Atmospheric Model
CSG	Coal seam gas
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DERM	Department of Environment and Resource Management
GCM	General circulation model
IPCC	Intergovernmental Panel on Climate Change
LoS	Level of Service
MoF	Method of Fragments
QCCCE	Queensland Climate Change Centre of Excellence
SEQ	South East Queensland

GLOSSARY

Term	Definition
Alluvial	Alluvial refers to deposits of clay, silt, sand, gravel, or other particulate material that has been deposited by a stream or other body of running water in a streambed, on a flood plain, on a delta, or at the base of a mountain.
Adopted Middle Thread Distance (AMTD)	AMTD is the distance in kilometres, measured along the middle of a watercourse, from the mouth or junction.
Allocation	A water allocation is an authority granted under Section 121 or 122 of the Water Act 2000 to take water.
Announced allocation	Announced allocation is a ratio (expressed as a percentage), which is announced from time to time by the Resource Operation Licence holder which sets a limit to the amount of supplemented water which a water allocation holder can divert during the water year as a proportion of the water allocation holder's nominal volume. The announced allocation may increase but cannot decrease during a water year.
Aquifer	An aquifer is a body of permeable material or rock, capable of transmitting significant amounts of water underlain by impermeable material and through which underground water flows.
Artesian (water)	Artesian water is water that occurs naturally in, or is introduced artificially into, an aquifer, which if tapped by a bore, would flow naturally to the surface.
A-depletion	A-depletion is the depletion (expressed in millimetres) in soil moisture from the maximum soil moisture capacity that a crop can withstand before it requires watering to sustain it. Once the A-depletion value falls below the nominated value, the allocation holder starts placing irrigation water orders to restore the soil moisture capacity to the nominated A-depletion value.
Authorisation	An authorisation refers to a licence, permit, interim water allocation or other authority to take water given under the Water Act or the repealed Water Act, other than a permit for stock or domestic purposes.
Annual Proportional Flow Deviation (APFD)	APFD refers to the statistical measure of changes to flow seasonality and volume in the simulation period.
Baseflow	Baseflow is the natural streamflow derived from underground water seepage from aquifers and/or through the lateral movement of water through soils and into the stream. At times of peak flow, baseflow represents only a small proportion of total flow, whereas in periods of drought, it may represent all of the flow.
Basin	A basin is the total area from which water drains to a river system, or a grouping of adjacent river systems. In geological terms, a basin is defined as either a broad tract of land in which the rock strata are tilted toward a common centre, or a large, bowl-shaped depression in the surface of the land or ocean floor.
Benefited/Supplemented groundwater area	A benefited/supplemented groundwater area contains aquifers that are recharged from augmented surface water supplies from water storage structures.
Bore	A bore is a hole drilled to extract, recharge or investigate groundwater resources. In the Water Act, it means a shaft, well, gallery, spear or excavation and any works constructed in connection with the shaft, well, gallery, spear or excavation, which taps the aquifer.
Calibration model	A calibration model involves the modelling of flows, extractions, operational rules and infrastructure that occurred historically.
Catchment	A catchment is an area, bounded by natural topographic features such as hills or mountains, from which a drainage system derives its water.
Confluence node	A confluence node is defined as a node representing the confluence of two watercourses. These watercourses may be supplemented or unsupplemented streams.
Current development	The current development case is modelling the existing entitlements within the system, to the degree to which they are presently operating. Authorisations are set to take only the water they are currently accessing, as indicated by data investigation reports and knowledge of the system operation.
Dam	A dam is works that include a barrier, whether permanent or temporary, that does, or could, or would, impound, divert or control water; and the storage area created by the works.

Term	Definition
Discharge (water)	Discharge is the rate at which a volume of water passes through a cross-section per unit of time; measured in cubic metres per second (m ³ /s) or in megalitres per day (ML/d).
Distribution efficiency	Distribution efficiency is the efficiency of the system in delivering water from the dams to the users. This is determined by dividing deliveries by releases. (Note: this often excludes hydropower releases and deliveries).
Data Modification Module (DMM)	DMM is a program used to adjust inflows using recorded flows downstream.
Drawdown	Drawdown is the lowering of the water table resulting from the extraction of water.
Entitlement	A water entitlement is a water allocation, interim water allocation or water licence.
Environmental flow	Environmental flow is the flow required to sustain a healthy environment. The release of water from a storage to a stream to maintain the healthy state of the stream.
Environmental Flow Objective (EFO)	An EFO is a flow objective associated with a water resource plan (WRP), for the protection of the health of natural ecosystems for the achievement of ecological outcomes.
Event duration	The event duration for a flow at a point in a watercourse, means the period of time when the discharge is greater than or less than the level necessary for a particular riverine process to happen.
Full development case	The full development case is modelling the full use of existing entitlements within the system. Authorisations are set to take all the water they are allowed to, regardless of climate or other factors not specifically mentioned in the licence. Generally, the full development case represents a higher level of use than the current development case, as it can include defunct licences and sleepers.
Headwater	A headwater reach is the source and upper reaches of a stream.
Hydrograph	A hydrograph is a graph showing the change in streamflow discharge at some location over time.
Hydrologic model	A hydrologic model is a computer program that simulates streamflows, water losses, storages, releases, in-stream infrastructure, water diversion and water management rules within a river system.
Infiltration	Infiltration is the downward entry of water into soil through the soil surface.
Interim Resource Operations Licence (IROL)	An IROL is a licence granted under Section 175 of the Water Act. An IROL authorises the holder to interfere with the flow of water to the extent necessary to operate water infrastructure to which the licence applies. IROLs may be granted in relation to existing infrastructure in an area where a resource operations plan (ROP) has not been approved or proposed infrastructure.
Interim Water Allocation	An interim water allocation is an authority under the Water Act to take water managed under an IROL or ROL that represents a volumetric share of water and any conditions attaching to the authority.
Integrated Quantity-Quality Model (IQQM)	IQQM is a computer program, with associated statistical analysis and reporting programs, which simulates daily streamflows, flow management, storages, releases, instream infrastructure, water diversions, water demands and other hydrologic events within a modelled area.
Licence	A water licence is licence granted under chapter 2, part 6, division 2 of the Water Act for the taking and using of water or for interfering with the flow of water. A water licence does not have a specified performance.
Licence volume	Licence volume is the nominal volume of water that may be taken under a water licence in one water year. The amount drawn may be subject to other licence conditions or allocation rules.
Link	A link in an IQQM model is a reach of river between two nodes.
Low flow regime	The low flow regime for a watercourse refers to magnitude, frequency, duration, timing and rate of change of low flow through the watercourse.
Mean Annual Diversion (MAD)	The mean annual diversion is the average volume of water taken by an allocation or group of allocations in a year. It is calculated by adding the total volume of water taken over a period of years and dividing by the number of years in that period. The calculation is performed on a water year basis.

Term	Definition
Mean Annual Flow (MAF)	The mean annual flow is the average volume of water in a year that would flow past a point and is calculated by adding the total volume of flow over a period of years and dividing by the number of years in that period. The calculation is performed on a water year basis.
Node	A node in an IQQM model is used to represent a point on a river system where certain processes occur. The node type identifies the rules and parameters that are used by the model to simulate the relevant processes at a given location.
Nominal operating volume	A nominal operating volume of a storage is the level that is to be maintained during the specified period by releasing extra water (if available) from the upstream storage.
Nominal volume	A nominal volume is the volume of water, in megalitres, that represents the proportional annual volumetric share of water available to be taken by holders of water allocations in a priority group or a water allocation group.
On-Farm storage	An on-farm storage is a private storage constructed on a property to store water.
Order time	Order time is the number of days in advance that an order has to be made to ensure that the ordered water arrives on time.
Over order factor	An over order factor in an IQQM model is the factor by which water orders need to be increased to account for operational inefficiencies in a water supply scheme. This factor does not account for transmission losses.
Overland flow water	Overland flow water is water, including floodwater, flowing over land, other than in a watercourse or lake after having fallen as rain, or after rising to the surface naturally from underground, or in any other way.
Pre-development case	The pre-development case is created by removing all infrastructure, diversions and operation rules from the full development case. No adjustment is made for the effect of land clearing, natural changes in river course, or climate change.
Performance indicators	Performance indicators are measures that are calculated and stated in the WRP with the purpose of assessing the effect of allocation and management decisions or proposals on water entitlements and natural ecosystems.
Plan Area	The Plan Area is the total area to be managed under the WRP.
Pseudo crop method	The pseudo crop method involves the arrangement of evaporation, crop factors and planted area in an IQQM model to ensure that the full amount of water allowed to be diverted each year is diverted if available.
Reach	A reach in an IQQM model is a series of nodes connected by links. A river reach refers to a defined stretch of river.
Recharge (of underground water/aquifer)	The replenishment of underground water by the gradual downward movement of water from the soil to the water table, by actions such as rainfall, overland flow or infiltration from streams percolating through the unsaturated zone; the volume of water added to the amount of water stored in the aquifer over a particular period; by artificial means, such as direct injection.
Resource Operations Licence (ROL)	A ROL is granted under Section 108 of the Water Act and in accordance with a resource operations plan (ROP). It authorises the holder of the licence to interfere with the flow of water to the extent necessary to operate the water infrastructure to which the licence applies.
Resource Operations Plan (ROP)	A ROP is used to implement a WRP in specified areas. It details the operating rules for water infrastructure and other management rules that will be applied in the day-to-day management of the flow of water in a reach or subcatchment. ROP specifies water access rules, environmental flow rules, trading rules, the conversion of licences to water allocations and monitoring requirements.
Return flow	Return flow is the water that flows out of the end of a channel system and back into a natural river system without being diverted by any user.
Riparian	Riparian refers to the area adjacent to a watercourse. Riparian access refers to an authority for an owner of land abutting a watercourse to take water for stock watering or domestic purposes.
River section	A river section in an IQQM model comprises a chain of links and nodes commencing with a headwater inflow node or a confluence node and finishing with a confluence or end-of system node.
Riverine	Riverine refers to rivers and their flood plains.

Term	Definition
Routing	Routing occurs as water flows from one point to another in a system. Routing is the attenuation (flattening out) of the flow hydrograph as water moves down the system.
Scenario/Simulation model	A scenario/simulation model involves a fixed set of parameters for infrastructure, rules and licences. Scenario/simulation models are used to produce a representation of what may occur in the system, if the selected set of parameters were in place.
Simulation period	The simulation period is defined by the start and end dates of the model.
Sleepers	A sleeper is a licence which is current, but not in use.
Subartesian water	Subartesian water is water that occurs naturally in, or is introduced artificially into an aquifer, which, if tapped by a bore, would not flow naturally to the surface.
Subcatchment area (subarea)	A subarea is a portion of a catchment within the Plan Area. A subarea may be physically defined or simply a result of breaking the catchment into smaller sections for the purposes of modelling.
Supplemented	Supplemented refers to a water supply where the natural flow is reduced or increased by a dam or some other water storage facility.
Surface water	Surface water is water that is on the earth's surface, such as in a watercourse, spring, lake or reservoir.
Sustainable management	Sustainable management allows for the allocation and use of water for the physical, economic and social wellbeing of people within limits that can be sustained indefinitely while protecting the biological diversity and health of natural ecosystems.
Transmission losses	Transmission losses are losses from surface water (other than into defined groundwater systems) as it flows from one location in a system to another. This can include evaporation, seepage, uptake by plants and unauthorised usage.
Tributary	A tributary is a stream that joins another stream or body of water.
Tributary recession factor	The tributary recession factor in an IQQM model specifies the percentage of each tributary inflow which can be used by downstream water users as part of the supplemented water supply.
Underground water	Underground water or groundwater is water found in the cracks, voids or pore spaces or other spaces between particles of clay, silt, sand, gravel or rock within the saturated zone of a geologic formation. In the saturated zone, all cracks, voids or pore spaces are completely filled with water-not to be confused with soil water in the unsaturated zone where voids are filled with both air and water. The upper surface of the saturated zone is called the water table.
Underground water levels	The physical measurement of the distance from the natural surface or reference point to the water surface in a subartesian bore when it is in a fully recovered state. A negative value indicates that the water level is below the reference point. Underground water level measurements provide an estimate of the 'depth to the water table'-or upper surface to the saturated zone-where the reference point is the natural surface.
Unsupplemented	Refers to water in a watercourse that is not supplemented from storage or diversion facilities.
Water year	A water year is a continuous 12 month period starting from a specified month, used for the accounting of entitlements.
Water Allocation Security Objectives (WASO)	WASOs are objectives that may be expressed as performance indicators and are stated in a WRP to ensure protection of a water entitlement to obtain water in accordance with a water allocation.
Water Supply Scheme (WSS)	A WSS is a water infrastructure development designed and constructed for storage, supply and distribution of water from and to a watercourse.
Water harvesting	Water harvesting is an entitlement to take unsupplemented water from a watercourse during specified high flow events and generally involves diverting water into an on-farm storage for later use. Water harvesting is licensed.
Weir	A weir is a barrier constructed across a watercourse below the banks of the watercourse that hinders or obstructs the flow of water in the watercourse.
Annual Exceedance Probability (AEP)	The probability that a given total accumulated over a given duration will be exceeded in any one year.
Average Recurrence Interval (ARI)	The average, or expected, value of the periods between exceedances of a given total accumulated over a given duration.

Term	Definition
Disaggregation	In stochastic generation, the process by which temporally-coarse data (e.g., annual data) are transformed into temporally-finer data (e.g., daily data).
Downscaling	In climate change analysis, the process by which spatially-coarse climate data (e.g., 200×200 km ² data from a GCM) are transformed into spatially-finer data (e.g., 5×5 km ² data).
Exceedance probability	Probability that an event of specified magnitude will be equalled or exceeded in any defined period of time, on average. In the context of natural resource management, examples of events include storms, floods, earthquakes, algal blooms and droughts.
Level of Service (LoS)	The frequency, severity and duration of restrictions that the community can expect. Commonly the LoS is defined as the annual probability that the volume in a water storage falls below some trigger volume.
Method of Fragments (MoF)	In stochastic data generation, a commonly used method used to disaggregate data at coarse time step to a finer time step by resampling fragments of the historical data.
Percentile	The value of a variable below which a certain percentage of observations fall.
Replicate	A single stochastic realisation.
Stochastic analysis	The treatment of model inputs as random variables that are sampled from an underlying probability distribution. These inputs are fed through a model (e.g., a hydrological model) yielding outputs that are themselves stochastic in nature.

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